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OF THE

AMERICAN WELDING SOCIETY

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American Welding Society

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AMERICAN WELDING SOCIETY
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JOURNAL

Volume 5 October, 1926 Number 10

Program
Fall Meeting
American Welding Society
Buffalo, N. Y.

November 16, 17, 18 and 19, 1926

Headquarters
Technical sessions, exhibitions, demonstrations—*Broadway Auditorium*

International Welding Exposition

One of the largest Welding Expositions will be held in connection with this fall meeting showing new developments in welding apparatus and supplies. A unique feature of this Exposition will be an exhibit of a large variety of welded products. The Exposition will open on Tuesday afternoon, November 16, the day preceding the Annual Fall Meeting of the Society, and will close on Friday, November 19 at 5 p. m. It will also be open on Tuesday and Wednesday evenings.

Inspection Trip and Buffet Supper

On Friday afternoon, November 19, 1926, an inspection trip has been arranged to Niagara Falls. Members of the Society and their guests will view the Falls from the American side with a short inspection trip through the Niagara Falls Power House. This will be followed by a buffet supper on the Canadian side and then a special illumination of the Falls will be shown, returning to Buffalo late in the evening. The exact time and place for assembly of members and their guests will be announced at the Exposition Headquarters. Reservation per person for this trip and supper is $1.75.

Dinner Dance

A Dinner Dance will be held Thursday evening at the Hotel Statler. Special arrangements have been made as to entertainment features which will insure a good time for everyone who attends. In addition, arrangements have been made for an excellent dinner. Reservations should be made at once by applying to

Mr. Carl D. Miller, 510 Morgan Building, Buffalo. Price per plate, $6.

Attendance

Indications are that there will be several thousand people in attendance at the various technical sessions, inspection trips, committee meetings and exhibits, including representatives from all parts of the United States and Canada. Several exhibits of European manufacturers are also included.

Hotels

Special arrangements have been made with a number of hotels, some of which are listed below, with the minimum rates for single room with bath:

Hotel Broezel, $3; Buffalo, $2.50; Greystone, $2.50; Lafayette, $3; Lenox, $3; Stuyvesant, $2.50; Statler, $4; Touraine, $3.

Badges

Admission to exhibit hall to be by badges only; all members of the American Welding Society and exhibitors, including their authorized representatives, will be furnished with admission badge free of charge, other visitors will be charged 25c. for the admission badge, which includes copy of official program.

TECHNICAL PROGRAM

WEDNESDAY, NOVEMBER 17, 1926

Morning

10 a. m. to 12 m.

"Welding of Locomotive Parts," M. Gjersten, Master Welder, Northern Pacific Company.

"Organization of Welding on the Railroad," F. H. Williams, Assistant Test Engineer, Canadian National Railways.

Afternoon

2 p. m. to 4 p. m.

"Structural Steel Joints Fundamentally Designed for Arc Welded Connections," A. M. Candy, General Engineering Department, Westinghouse Electric & Manufacturing Co.

"Tests on Welded Roof Truss," H. H. Moss, Linde Air Products Company.

THURSDAY, NOVEMBER 18, 1926

Morning

10 a. m. to 12 m.

"Welding Science in the Engineering Curriculum of Universities." Prof. W. P. Turner, Purdue University; Prof. B. L. Lucas, Mississippi Agriculture and Mechanical College; Prof. S. T. Hart, Syracuse University, Prof. O. D. Rickly, Ohio State University; Prof. F. V. Larkin, Lehigh University.

Afternoon

1:30 p. m.

Welding Wire Specifications Committee. C. A. McCune, Chairman.

2:30 p. m.

Meeting of the American Bureau of Welding. The remarkable progress made by the welding research department of the American Welding Society (American Bureau of Welding) will be a source of satisfaction to the members of the American Welding Society and the welding fraternity.

Evening

7 p. m.

Dinner Dance. Details are given in first column.

FRIDAY, NOVEMBER 19, 1926

Morning

9 a. m. to 10:30 a. m.

Short technical session on *"Welding in a Gaseous Atmosphere,"* including demonstrations, and exhibitions will be made by Mr. P. P. Alexander and Mr. R. A. Weinman of the General Electric Company.

10:30 a. m. to 12:30 p. m.

Meeting of the Board of Directors, American Welding Society.

Afternoon

3:00 p. m.

Inspection trip.

Details are given in first column.

A SPECIAL MESSAGE

The American Welding Society owes its remarkable progress and success to the program of activities incorporated at the time the Society was first conceived. This program had at its inception a desire to serve and serve unselfishly not only the manufacturers of welding apparatus, but particularly a vast number of concerns that use welding as part of their daily work and also to benefit the public at large.

Among other things, this program included two annual get-together meetings, at which all of our members could meet in a social way and create a spirit of good fellowship and at the same time provide an opportunity for talking over accomplishments and difficulties with others interested in the same line of endeavor.

The coming Fall Meeting of the Society, which will be held in Buffalo, will more full carry out the conception of the founders of the Society by having connected with it an International Welding Exposition. The technical papers have been carefully selected to cover timely subjects of interest to the welding fraternity. All indications are that there will be a large attendance. Every member of the Society should plan to be present and help make this meeting an outstanding success.

Among the many attractions will be the trip to Niagara Falls. It is always worth while seeing these mighty falls and we will also be able to see how they are being harnessed in the service of mankind, as the inspection trip includes also a trip through the Niagara Power House. There will be a special illumination of the falls in honor of our inspection trip. A special dinner-dance has been arranged

which is sure to be enjoyed by all those who attend.

Don't forget the ladies; they are welcome. There will be much that will interest them.

DISCUSSION OF FALL MEETING PAPERS

The Meetings and Papers Committee desires to secure a complete discussion of the papers which will be presented at the Fall Meeting of the Society in Buffalo in November.

In order to allow members of the Society an opportunity to become familiar with the substance of these papers, they have been printed in advance in this issue of the Journal. Those members who find it impossible to attend can send in written discussion of any paper to Society headquarters and it will be read at the meeting.

WELDED RAIL JOINTS

The Welded Rail Joint Committee held a meeting in Cleveland on October 6 in connection with the Annual Convention of the American Electric Railway Association. About forty Way Engineers were present. One item on the calendar included a review and discussion of the results of a series of scientific tests made by the Bureau of Standards in determining stresses in joints in the street and under the repeated impact testing machine. This series of tests was made possible by the use of an electric recording strain gage device developed by the Bureau of Standards and called the "Telemeter." The committee was unanimous in the opinion that further tests along this line should be made with the elimination perhaps of a number of the variables by selecting a particular type of joint for a series of studies. There was also presented an important report from Lehigh University embodying the results on a large number of shear tests on specimen joints prepared under the direction of the committee in order to develop, if possible, an improved type of seam welded rail joint. It is planned to publish the results of both the telemeter and shear tests in the near future in a Fifth Progress Report of the Committee on Welded Rail Joints.

PAPERS ON WELDING FEATURED

Members of the Society and others of the welding fraternity will be pleased to note that the American Iron and Steel Institute will devote one of its sessions to a paper on "Welding of Iron and Steel," by Prof. C. A. Adams. The American Institute of Steel Construction, which organization is cooperating with the American Bureau of Welding in the proposed Structural Steel Investigation, will devote a session of its annual meeting to a paper on "Fundamentals of Welding and Their Possible Application in the Structural Field," by W. Spraragen, Secretary of the American Bureau of Welding.

SECTION ACTIVITIES

Chicago

One of the most successful meetings of this section was held on October 1. More than sixty people were present. Mr. H. H. Moss of the Linde Air Products Co. was the speaker of the evening. His subject was "Welding Roof Trusses," which included some very interesting and elaborate tests carried out some time ago at the Buffalo plant of the Linde Air Products Co. His lecture was accompanied by lantern slides, and it was clearly evident by the discussion which followed that those present were extremely interested in the subject. Mr. G. O. Carter discussed at length the subject of welding in general and particularly as applied to pipe lines. His remarks were also of much interest to the audience.

Boston

The Executive Committee of this section held a very enjoyable meeting at Gloucester, Mass., on August 29. A basket luncheon and picnic was enjoyed by the members of the committee and the ladies. After the business meeting and luncheon a bathing party was organized.

A very interesting meeting of the Boston section is planned for the evening of October 21 at Lynn, Mass. The features of the evening will be a paper on "Hydrogen Welding," demonstrations of hydrogen and atomic welding and also a demonstration on cutting of boiler plate, tank plate and steel

castings by illuminating gas, accompanied by a lecture. Prof. C. A. Adams of Harvard University will talk on "Welding Progress Linked with Research." Prof. R. H. Smith of Massachusetts Institute of Technology will give a brief talk on "Teaching of Welding in Engineering Schools," and Mr. J. D. Wright, General Electric Company, Schenectady, will present a paper on General Welding.

Portland

The regular monthly meeting of this section was held on September 30. Mr. W. P. Schuck gave a very interesting paper on "Cast Iron Welding." Considerable discussion followed on this subject. The following people were elected to serve on the national committees of the Society: R. I. Smythe, National Board of Directors; G. C. Dierking, Membership Committee; W. P. Schuck, Revision of By-Laws Committee.

Northern New York

About sixty members and guests attended the first meeting of the season on September 29 at Pittsfield, Mass. During the afternoon Mr. R. E. Wagner of the General Electric Company conducted an inspection trip through the Pittsfield factory of the General Electric Company to see applications of welding as used in the manufacture of transformers. After this an excellent dinner was served in the works' restaurant. The regular meeting was held at 7.30 p. m. Mr. H. W. Tobey of the Research Laboratory read a paper on "Electric Resistance Welding." This paper was supplemented by lantern slides and a large variety of welded samples. A film by the Department of the Interior and the Air Reduction Company was exhibited, showing the applications of gas welding and the manufacture of gas welding appliances.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to Society headquarters.*

POSITIONS VACANT

V-35. Owner of welding shop and radiator company would like to secure experienced man to take charge. A permanent job is offered to all-round mechanic experienced in gas and electric welding. A salary from $50 to $60 per week would be given to start according to experience of man. For faithful service, a percentage of business done would be given.

V-36. Nine experienced arc welders wanted. Welders required to do night work on a 10-hour shift from 7:30 p. m. until 6:00 a. m. Will alternate night gang with day gang. Position steady and with well-known coil pipe company.

SERVICES AVAILABLE

A-50. Would like to get in touch with reliable firm who contemplates going into the Art of Forge-Lap Welding, for manufacturing Boiler Shells, Chemical Apparatus, Ammonia Pressure Vessels of all description, Pulp Digesters, Air Receivers, Steam Kettles, Car Tanks, etc. Am capable of designing and installing the necessary machinery for either Universal or special manufacture, also of giving instructions with relation to same. I have been thirty years in the profession.

Welding Science in the Engineering Curriculum of Universities*

PROF. S. T. HART,†

At the request of the American Welding Society I have endeavored to tell, in this paper, what is being done in American universities to study the science of welding; also what they have in mind to do in the near future.

First, I wish to congratulate the American Welding Society on its united efforts in the cause of the science of welding. All the modern forms of welding are banded together for the common good of the science and efforts are not expended in useless competition. When there were a large number of small companies, some good and some poor, some doing well in a business way and some not, the science of welding was not advanced, but now with a united society embracing all companies engaged in welding and many of these companies maintaining a force of research men, the science has made great strides.

Many of our industries are the result of some accidental discovery or the result of years of development, but welding was started by scientific research men, such as Fouche, Picard, Goldschmidt, De Meritens, Bernardos, Thomson and others.

Electric welding is about forty years old, Thermit welding thirty years old and gas welding twenty-five. Only twenty-five years old! Just a boy out of college starting to learn the real business of life! When we look at the size of the American Welding Society and the industries it represents, welding is certainly a wonderful child in its growth and development.

Welding was started by men of science in research laboratories. As in the case of one of the newest developments, the Atomic Hydrogen torch, the company says: "From the realm of pure physics and chemistry comes the discovery." Men working in the old subjects of physics and chemistry, with gas and metals that had been known for years, in the highly theoretical laboratory, made a combination that is very practical, useful and a very wonderful step in the right direction.

In the early days of welding some companies ran away with the inventions and even went so far as to make some of their instruments so special that no one but themselves could repair them, did no research work or anything to make the foundation of the industry broad and firm; but I am glad to say that this state of affairs does not exist today and in fact only existed for a short time. The industry soon started to rebuild on the firm foundation of science and on this base I know the schools can be of great help.

When we train our men today in the schools, we aim to equip

*To be presented at the Fall Meeting of the A. W. S., Buffalo, November, 1926.
†M. E., Dept. Syracuse University, Syracuse, N. Y.

them with the fundamentals so that they may have a broad basis on which to build when we send them to you.

Before starting to write this paper I made a canvass of all the companies in this country that are listed as making welding apparatus of any kind. A letter was sent asking the company to give information in the form of pictures or slides, of any apparatus they had provided for schools. About 100 of the higher institutions of learning were asked to fill out a questionnaire, given below.

QUESTIONNAIRE

Have you welding apparatus?
Electric
Gas
Thermit
Type and amount of apparatus.....
.....
.....
Do students use the apparatus?.....
Are lectures given using the apparatus for demonstration .....
Is welding mentioned or explained to the students?.....
To what extent? .....
.....
.....
Would you put instruction in welding on a par with machine shop?.....
wood shop?..... forge shop?..... foundry?.....
In your opinion of what value is welding instruction? .....
.....
.....
.....
In your opinion what is the future of welding?.....
.....
.....
.....
Remarks .....
.....
.....
.....

SUMMARY OF RESULTS

Taking the number of universities heard from as the total and figuring the results on the percentage basis we have:

Percentage using Electric apparatus,	30 per cent
" " Gas apparatus,	60 per cent
" " Thermit apparatus,	10 per cent
Per cent of the universities who have the students use the welding apparatus,	47 per cent
Per cent of the universities who give lectures on the science of welding,	50 per cent
Per cent of the universities who explain welding to the students,	81 per cent

To the question, "To what extent" the following answers were given:

"Part of the required course."
"Average amount of explanation given."
"No instruction given at present time."
"Only to afford a comparison with welding at the forge."
"Average amount of explanation given."
"Ten lessons."
"Average amount of instruction given."
"A small amount to Freshmen of Engin. and Ind. Colls."
"Several courses in Ind. College."
"One hour."
"About 30 min. in connection with each exp."

"Lecture and demonstration."
"One or two lectures to Seniors."
"Demonstrated by Instructor."
"Average amount of instruction given."
"To only a limited extent."
"Too brief courses."
"None."
"Limited."
"5 clock hours."
"Average amount of instruction given."
"Briefly."
"Try to give the main principles."
"Average amount of instruction given."
"Small (in lectures concurrent with shop)."
"Average amount of instruction given."
"As required in shop practice."
"Average amount of instruction given."
"Used for repair work and students become familiar with it."
"Several hours."
"Average amount of instruction given."
"In courses in Design."
"Welding different materials."
"One lecture."
"Average amount of instruction given."
"In connection with courses in forging and not as a separate course."
"One period of four hours."
"About two-thirds of an hour course for one semester."
"Brief lectures."
"Carefully."
"Slight."
"During demonstration."
"Elementary principles in welding."
"Limited."
"In connection with machine shop design problems."
"Explained in machine design."
"Other types explained."
"One 2 hour lecture."
"Average amount of instruction given."
"In applications of electricity."
"Only casually."
"Lectures and demonstrations."
"In courses on Mech. Tech., Shop Equipment, etc."

Sixty answers were received to this questionnaire. In this way, by asking both the companies and the universities, I had two opportunities to find out what the schools have in the line of welding apparatus. The questionnaire was designed to give in a few words the story of what apparatus the colleges have, how it is used, what information the students are given in the form of lectures and under "Remarks" it was hoped to get their plans for the future of welding. Practically all the statements as to the importance and future of welding are the personal opinion of the men who filled out questionnaires and not necessarily the opinion of the schools.

Academic freedom allows all of us to speak on almost any subject as we personally see fit and not necessarily always as the school, as a whole, thinks. Therefore, the personal equation has to be taken into account in some of the answers.

I am very much pleased and gratified with the cooperation that has been given me and the answers show that a great many teachers are fully awake to the subject of welding.

After looking over the summary of the questionnaire, some of you may say, "They do not pay much attention to welding," "they are behind the times," etc. You may be right, but let me explain. You men are specialists in something in the welding line—welding is your work, welding is your play and, in some cases, welding is your God. Our students do not all go in to your companies. Statistics show that about 75 per cent of our engineering students go into industries as a whole—steel, copper, machine tools, automobiles, textiles, etc. The other 25 per cent go into research, consulting, teaching or go out of engineering. Now, if our graduates are spread over so large a field, we must give them such training in the main as will fit them to start in any one of the different lines.

We have often figured out that if a student took all the subjects that would really be of use to him it would take him twenty-five years to finish his course, but as we have him for only four years, in most cases, and most of the students are normal men who wish to mix some sports and social life with their study, shops and laboratories, we must be very careful what we put into the curriculum. In the main, we feel that the engineering student has a well-balanced curriculum for the work that industry wishes him to do. As a proof of this the number of graduates asked for by industry this year was about three times as great as the number available.

If our engineering courses are already full, how can we give the proper training in welding science? A manufacturer finds that he can purchase a machine that is more efficient than the one he has, will not take any more room, will do the job better than it has been done; therefore he will generally buy that machine. This case of the manufacturer is a picture, as I see it, of the welding science. Welding has taken the place of some parts of foundry work, some forge work, helps in the machine shop, goes into construction and many other phases of engineering work, and, insofar as it supplants the work now given in the engineering schools, it should be given the time and thought of the work it supplants.

As welding will be used more and more in the building of bridges, study and experiments should be made for new forms of structural steel. In design we shall be able to use a lower factor of safety, or factor of ignorance as it is sometimes called, for if welding is used to join the parts and the joint can be made as strong as the parts, and by certain inspection the true condition of the joint may be known, a large amount of material will not have to be put in as a factor of ignorance. I feel that some adaptation of the instrument now used to inspect partly finished turbine wheels can be used to try the magnetic flux through the weld and therefore see, as it were, the entire inside of the weld. When this is accomplished, we shall no more hear that "a good weld is all right, but how do we know that it is a good weld?"

As welding originated in Europe, they have made some developments that we might well copy, but in this paper we are confining ourselves to American schools and industries.

It may be of interest to give a few of the statements that came to me under the head of remarks on my questionnaire:

"Instruction in welding is of great metallurgical value."

"The students enjoy the work and derive a good deal of benefit from it."

"Perhaps the most important method of joining and is therefore necessary in design."

"Welding deserves a great deal more attention than we have time to give it."

"We intend to put in a course this winter."

"Every engineer should know what can be done by welding."

"We give a twelve weeks' course for welders."

"So much used—all should know it."

"A knowledge of welding possibilities is a necessity for an up to date designer."

"Absolutely necessary."

"Each student is required to make a certain number of welds."

These are just a few of the remarks I received which show the general trend. In many cases the cry was—"we have no time or space."

Now, I would like to make a few suggestions as to how you, who represent the industries, can work with us to produce the best results. Visit the universities in your district, get acquainted with the men who are interested in your line and offer a speaker on welding science. I suggest at least two talks—one on what welding is and what it does, and one talk on design, test and economics of welding. These talks should be given by a man who knows his subject and who knows how to present it to students. Many of the schools would welcome samples of welding.

Some of these samples could be used in a test problem in the testing laboratory to test the strength of the weld. Small pamphlets on welding for distribution to interested students would be gladly received. Tabulated data regarding the strength and comparative cost of welding with other forms of joining is needed in our work. In certain cases graduate students and men on theses would be glad to work on some research problem in the science of welding.

The work of Professor McKibben, Prof. A. S. Kinsey, Dr. A. Krebs and the United States Bureau of Standards in the Science of Welding is of great interest to me and I believe is along the right lines.

I feel that I have the privilege of making the above suggestion because I was a teacher of welding in the early days; also, made some simple investigations in those days to help the science.

In closing I wish to thank the industries and the universities for their cooperation and help in this paper.

Welding Science in the Engineering Curriculum of Universities*

O. D. RICKLY†

During the past fifteen years the welding industry has made a phenomenal growth paralleling that of the automotive industry. Originally used for making repairs, then gradually working its way into production of light steel work, it has finally reached the point where it is furnishing competition to the rivet in the construction of plate work such as storage tanks and boilers, and, according to recent reports, welding has also been used in place of rivets in the erection of structural steel buildings. Not so many years ago drums of oxygen and hydrogen were only to be found in the experimental laboratory. Now there is such a net work of delivery stations over the country that it is possible to procure these gases anywhere and any time.

With the practical side of welding making such far-reaching strides, the question may well be asked as to what the various engineering schools are doing in the way of teaching the welding science. The mechanics of riveted joints has been taught for years and if welding is to replace riveting, our embryo engineers naturally must be taught the mechanics and construction of welded joints. It is the purpose of this brief paper to discuss this problem.

Since representatives of other schools are also expected to contribute to this discussion, the author will limit himself to conditions as they exist at the school which he represents.

Frankly, to date there has been very little done with the teaching of the theoretical side of welding. The reasons for this, as given below, are not solely the author's views but are the consensus of opinion of the members of the teaching staff concerned with the problem.

In the first place, as has previously been stated, the welding industry has been developing so rapidly that what is new today will become obsolete in a short time. If the development of a new industry be represented by a curve, it will be noted that it starts out with a slow rise. After the value of that industry is once recognized the development curve rises rapidly until exhaustive research in all phases of the industry has been made, when the curve again flattens out. At this point operations, processes, and equipment become standardized. It is also to be noted that research in any industry always lags behind the practical growth of that industry, so that data accurate enough upon which to base computations are usually obtained after the practical side has been roughly developed.

During the rapid development of a subject it is rather difficult

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to make a place for it on an engineering curriculum, for what is new one year is obsolete the next. It is only when sufficient accurate data from which fundamental principles can be formulated that a subject is considered. However, this does not mean that the subject is entirely ignored, but is usually treated along with subjects of a similar nature.

The welding industry is at present passing through this rapid growing stage, and if a prediction be permissible it would be that it is approaching the upper plateau of the development curve.

This is based upon the fact that a vast amount of research is being done by the various agencies interested in the industry. Engineering code makers have practically all formulated rules for construction and testing of welded joints. All this will produce data from which fundamental laws can be formulated whereby a design can be calculated and executed with safety.

After the weld is designed it still depends upon the skill of the welder for its calculated strength. Regardless of how carefully a weld is calculated and designed, that weld, because of the human factor, can be no better than the welder makes it. It is vital, to prevent the possibility of loss of life and of great property damage, that each weld should be flawless. For that reason every resource available should be called upon to make welding as nearly fool proof as possible so that all welds, regardless of the welder, will have their required strength. This phase of welding has, in the past, been a serious drawback to its advancement into the major fields of industry. Reports of recent tests indicate that this objection will soon be negligible.

From the practical standpoint, the welding industry has not been entirely left out of the curriculum. In the industrial shops of the university gas welding has been taught for the past ten years. In all the shop courses it is not the purpose to make experts in the various lines but rather to acquaint the students with the shop equipment and methods. They are also taught the limitations of shop equipment, so that in case, at some future time, they get into the design field they will not place impossibilities before the man who is to execute the designs. Welding has been handled in the same way. The instruction consists of lectures on welding equipment, filler rods and fluxes, welding procedure for the various metals, etc. Demonstrations are given by the instructor, after which each student is required to make two welds, one of steel and one of cast iron. This work is required of the mechanical engineering students and elective for the other engineering departments.

The electrical engineering department gives lectures and demonstrations on the electric forms of welding. The lectures cover the practical applications of electrical welding and power consumption.

In conclusion, it is thought that, as soon as sufficient data have been obtained upon which calculations can be based, welding methods and materials standardized and means devised for reducing

the personal factor to a minimum, welding will receive a great deal more consideration in the engineering college curriculum. The advantages of welding in the saving of time and materials are generally recognized and without doubt it is destined to become one of the most important of metal fasteners.

Welding Science in the Curriculum of Engineering Universities*

W. P. TURNER†

The art of welding by which two pieces of ferrous metal may be united into one solid piece has long been known and used by the industries in fabricating parts for machines, tools, implements, structures and an innumerable variety of other purposes. The old method of welding, in which the ends were shaped, heated in a forge or furnace and then hammered together by hand or under a steam hammer, is too laborious, too expensive and too uncertain for many modern day production jobs.

During the last twenty years new methods of welding have been developed which have opened up new fields for the application of welding, little before thought possible.

"Autogenous Welding," as the term is now generally understood, refers to the method whereby the parts to be welded are heated by a blow torch and the joint filled with metal of the same kind as the parts to be united melted from the end of a welding rod.

The flame of the torch is produced by burning oxygen and acetylene gas. The use of the oxy-acetylene blow torch has been made practical only since the development of methods for producing acetylene and oxygen gases on a commercial basis, which dates back about twenty years. Since that time the processes of welding have been rapidly developed. Improvements in types of torches, regulating devices and methods have brought the art to a state of near perfection and the field of application is broadening with tremendous rapidity.

Of equal importance with autogenous welding is "electric welding." In many cases these two methods are rivals in the same field, while in many other instances their paths diverge so clearly that there is little doubt in the mind of the engineer which of the two methods is best suited for his particular job.

There are two distinct but well defined methods of electric welding, one known as "arc welding" (either the metallic arc or the carbon arc), and the other as "resistance welding." The process of arc welding is in some respects similar to that of autogenous welding, but the process of resistance welding is quite different from either.

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In "metallic" arc welding the heat of fusion is produced by an electric arc struck at the juncture of the pieces to be welded. One of the wires conveying the electric current is attached to the work and the other wire is attached to a metallic welding rod called an electrode. By proper manipulation of the welding rod an arc is maintained at the joint, which immediately fuses the parts being welded and also melts from the end of the rod metal for filling the joint. In "carbon" arc welding, a carbon electrode is used in place of the metal electrode. An arc is struck between the work and the carbon electrode. The filling rod is melted in the arc and applied much the same as in oxy-acetylene welding.

In resistance welding, heat is generated at the joint by the resistance to an electric current of low voltage, but high amperage that raises the temperature to the welding point where upon the pieces are pressed together. This method of welding involves the use of a special welding machine fitted with special clamping devices for holding the pieces in their proper position and with mechanism for exerting pressure to unite the pieces after they have been properly heated. Resistance welding is probably more generally used in the manufacturing industries than any of the other methods, especially in cases where a great many pieces of the same size and shape are to be welded.

Another method of welding ferrous metal parts is by the Thermit Process, one quite different from either autogenous or electric welding but of tremendous value and importance for certain kinds of work. The field of usefulness for thermit is broad. It includes such jobs as welding broken rudder posts or stern posts of ships, joining rails for electric street car service, welding locomotive frames and even breaking up icebergs that menace navigation in the St. Lawrence River and Gulf during the early summer months.

Thermit welding is accomplished by producing liquid steel at a temperature estimated to be about 5000 deg. fahr. and pouring it into the joint between the parts to be welded where it is retained by a mold of sand that has been placed about the parts to be welded. The intense heat of the liquid steel is sufficient to fuse with and unite the metal parts being welded. When cooled, a union has been made equal in strength to the original. The unusual thing about this method of welding is the process of generating a temperature of approximately 5000 deg. fahr., a temperature nearly double that of liquid steel when tapped from a furnace. This intense heat is brought about in a crucible in which the thermit has been placed by a chemical reaction between the iron oxide and the finely divided aluminum of the thermit. After the reaction, molten steel is at the bottom of the crucible on which floats a slag of aluminum oxide.

The oxy-acetylene cutting torch or the electric carbon arc used for cutting steel parts, in cases where large masses of tangled steel structural beams are to be cleared away, steel ships dismantled or

for innumerable other wrecking purposes has proved to be of inestimable value. It has also become a most valuable tool in construction work, where it is used for cutting structural forms, heavy steel plates, steel forgings and castings. For certain kinds of cutting jobs, machines have been devised for supporting and guiding the cutting torch which has enabled cutting very irregular shapes with considerable accuracy. Similar machines are also used successfully for a variety of arc welding jobs. These machines are automatic in the entire welding operation.

While the different processes of welding and cutting referred to have already been highly developed and perfected and are recognized as standard processes that may be depended upon, the art of welding has by no means reached ultimate perfection and laboratory research will undoubtedly make possible other methods of welding quite as valuable as those already practised. One of the more recent discoveries applicable to welding operations is that wherein a flame of atomic hydrogen supplies the heat for fusion. Oxygen is not used. This process has been worked out at the General Electric research laboratory and developed largely by the work of Dr. Irvin Langmuir and others. Still other discoveries in the use of hydrogen for welding have been announced from the Thompson Laboratory at Lynn, Mass.*

The field of welding has broadened so rapidly that it would be useless to try to enumerate specific cases for its application. If welding operations were confined only to those of making repairs, then the field would be large enough to warrant attention, but when they also enter the fields of design and construction, welding becomes particularly interesting and demands serious attention. One notes with interest how this art of welding is affecting machine design. Parts of machines, such as frames, bodies, beds, legs, etc., which formerly were made of gray cast iron, are now built entirely of steel cut from standard structural shapes and assembled into a whole by welding. In many cases this change has increased strength, reduced weight and also reduced cost. In assembling structural steel frames and for tank construction, welded joints are fast replacing riveted joints and are giving most satisfactory service.

This rapid development of the art, with its many applications to the manufacturing industries, is demanding the attention of engineers in both industrial and educational work. Those who are following this art, and can visualize its future development, feel that it will be further developed with study and investigation, that its present field of usefulness is already established and that it is therefore worthy of a place in the curriculum of an engineering university.

The extent and thoroughness of a course in welding that may be administered as a part of a four-year course in an engineering school would be governed somewhat by the time allotted to the

*Note—"Two New Welding Discoveries" in *Power*, March 23, 1926.

subject and also by the equipment available for demonstrations and use by students. It is doubtful if sufficient time could be found in a regular engineering curriculum for giving to the student such a thorough knowledge of the art that would make him a successful or a practical welder, but enough time should be given to awaken in him an interest in the subject and to point out to him its great field of usefulness and to help him to know when he can call on this art of welding to help solve some of his difficult problems.

Excellent courses of instruction in welding have already been prepared by those who have helped to develop the processes. These courses of exercises have been arranged to give practice in welding from the simplest to the most complicated job. Thorough instruction is given in the use and care of all appliances and also on the nature of the gases used for autogenous welding or the electric current for electric welding. These courses, with modifications, could be well followed in any engineering shop labatory that proposes to give instruction in welding. Two things, however, are absolutely necessary to make the work and the time spent on this subject of value. First, there should be an instructor who knows the subject, its application to the industries and the processes involved, and second, the laboratory equipment should be modern and ample for handling a class without restricting the use of apparatus. Instruction should be given by lectures, demonstrations, and practice.

A well-equipped welding laboratory should have a number of complete welding stations with all the torches, tanks, tables and accessories that are used for autogenous welding and cutting. There should be complete welding stations for electric welding, showing the different types of arc welding machines and resistance welding machines. There should be also apparatus for demonstrating the methods of thermit welding. In addition to all this welding apparatus there should be testing devices for testing the strength and physical properties of the welds made. Also microscopes for examining the grain structure of the weld and testing devices for testing hardness, ductility, etc. There should also be provided laboratory equipment for carrying on advanced studies of the gases or the electric currents used for generating the heat and for the study of occluded gases in the metal which tend to make imperfect welds. A laboratory thus equipped, together with instruction given by a competent instructor, would offer a student an opportunity to gain information and skill in the art of welding that could hardly be equalled in any other way.

Courses of instruction in welding have already been started in a number of engineering schools. Laboratory equipment for both gas and electric welding and cutting is available, and good work is being done in spite of the fact that because of limited equipment and large numbers of students the work must be spread thin.

The art of welding might be further stimulated by establishing at some of the larger engineering universities complete welding

schools and it seems that this might be accomplished by agreement between the universities and the many manufacturers of welding equipment.

While it is true that the art has been highly developed and its application is fully realized, it must be remembered that much of its success still depends upon the individual skill of the welder who knows how and can make perfect welds.

There is no question in the mind of the writer of the value of instruction in the modern methods of welding given to students in engineering universities. The application of the art in the industries is already a powerful factor in revising old processes and it is destined to enter new fields of application yet undreamed of. Such an art should not be ignored.

Welding Science in the Engineering Curriculum of the Mississippi Agricultural and Mechanical College*

By Ernest L. Lucas†

The Mississippi Agricultural & Mechanical College was founded Dec. 18, 1878, under the Federal Land Grant Act and since that date its objective has been, without excluding other scientific and classical studies and including military science and tactics, to teach such branches of learning as are related to agriculture and the mechanic arts, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life.

Believing that industrial education is not a special scheme of training to be considered as separate and apart from the general scheme whereby higher learning is fostered, but that it is rather a reshaping of the general scheme whereby the commonwealth seeks to develop all classes of its citizens in intellectual vigor in industrial skill, and in liberal culture—to the end that the industries of the people may prosper, that their literature and their arts may be encouraged, and that the individual while being taught how to work may be fitted for life, the policy of the writer, as well as other members of the faculty, has been to give a broad course with considerable amount of practical work in shops and laboratories, as well as the theoretical courses. This theory has the conception that every man is a worker, bearing his own share of the common burden, trained for his work, skilled in the knowledge of his profession and informed beyond it; so that he may be bigger than the means by which he earns his bread, a citizen in whose care the interests of the nation will be safe.

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†Associate Professor Mechanical Engineering.

The engineering faculty has strived to keep abreast with the times and as new developments in science and in engineering have occurred, appropriate courses covering these fields have been adopted. So it was that in the fall of 1917 the writer offered an elective course in "Modern Methods of Welding Metals." Interest in this course grew rapidly and it was soon so popular, the course was substituted for one semester of "Machine Shop Practice" and required of all electrical and mechanical engineering seniors. A semester at this institution is of sixteen weeks duration, and all shop periods are three hours long, or forty-eight hours shop time for the course. It is understood, of course, that the time allowed is far too short to produce finished welders, which is also true of any other shop course offered.

Each student is furnished with copies of instruction manuals furnished by manufacturers of the equipment used here. Record cards are filled out in order that students may become familiar with commercial practice as they learn to handle the equipment. Our equipment consists of a welding torch, cutting torch, lead burner, regulators, and hose; a welding and cutting torch; two decarbonizing torches; several welding tables, vise stand, stock rack, preheating torch and truck, built by students from scrap material. This equipment is shown in the views, calling attention to the manifolds, and the novel stock rack. Test bars are prepared from various materials which have been welded and tested for tensile strength. Hammer tests are made to the destruction of the welds in order that the structure might be examined.

Manufacturers of welding and cutting equipment have furnished manuals, pamphlets, and periodicals which are great assistance in teaching the course and keeping keen the interest of the class. I feel very grateful to such concerns, but it seems that these concerns would realize the value of placing their equipment in institutions of this nature and offer more than they have in the past.

A brief outline of the course as given here follows:

Period 1. To acquaint the student with the outfit. Lecture covering history of acetylene gas, the oxy-acetylene torch, the various methods of welding metals, broad field of uses for the torch, various designs of torches, purpose and use of each part of the outfit, setting regulators, adjusting flame, etc. Demonstration: Assemble outfit, adjust regulators, adjust flame, change tips, etc. (No time for work by students.)

Period 2. Welding thin sheet steel. Lecture, welding of thin sheet steel, various types of joints. Demonstration and work: Butt, corner fillet and flange welds. Material: Two plates of steel 1/16 in. thick, 2 in. x 4 in. Welds were broken and opposite edges welded.

Period 3. Continuation plate welding, increasing thickness. Lecture explaining importance in preparation of stock and use of filler. Demonstration and work: Beveling stock, use of filler rod, weld plate. Material: Steel plate 3/8 in. thick, 2 in. x 4 in.

Period 4. Continuation of work begun in previous period. No additional material required.

Period 5. Cast iron welding. Lecture on structure of cast iron, malleable iron and galvanized iron; use of flux and puddling rod. Demonstration and work: Preparing metal for weld, lining up, clamping, preheating, etc. Material: Cast-iron plate ½-in. thick, 3 in. x 4 in.

Period 6. Filling-in and building-up castings and steel. Lecture, the use of the "putting-on tool." Demonstration and work: Take materials used in Periods 4 and 5, drill ½-in. holes in castings and fill-in; build-up a boss on steel plate.

Period 7. Welding cast iron. Demonstration and work: Broken iron castings are prepared for welding, set up, clamped and welded. Material: Such machine parts as brackets, gears, pulleys, etc.

Period 8. Welding pipe. Lecture, method of procedure in welding pipe, pipe lines, "tailor-made" fittings from standard pipe. Demonstration and work: Actual welding of pipe, making various types of fittings. Material: Various sizes of standard pipe.

Period 9. Bronze welding cast-iron pipe. Lecture, demonstration, work: Modern methods of joining cast-iron water and gas mains. Material: Cast-iron pipe.

Period 10. Welding structural steel. Lecture, recent developments and tests of welded structures compared with riveted structures. Demonstration, work and material: Assembly and welds for various types of structural joints of plates, channels and angles.

Period 11. Brass and copper welds.

Period 12. Aluminum welds.

Period 13. Cutting steel, wrought iron and cast iron.

Period 14. Decarbonizing auto cylinders.

Period 15. General use of the outfit.

Period 16. Tension tests of welds.

The Meetings and Papers Committee invites written discussion of any paper appearing in this issue. These discussions may be presented in person at the Fall Meeting of the Society in Buffalo or sent in to Society headquarters to be read at the meeting.

Welding of Locomotive Parts by the Oxy-acetylene, Electric, and Thermit Processes*

G. H. GJERTSEN†

As it would be impossible to cover the entire field of welding of locomotive parts by the three principal processes, namely, the oxy-acetylene, electric and thermit, the contents of this paper will be confined as much as possible to the major welding operations and to such other operations that are most common in the general construction and maintenance of locomotives in general.

The large number of parts and variety of the metals involved will no doubt allow room for interesting discussion regarding the most practicable and most desirable method to use, where adequate equipment is available, and competent operators are at hand to carry out the work to the best advantage on work that may be successfully performed by more than one of the processes outlined.

The choice of method to be used should only be made after due consideration of several factors, such as the kind of metal to be welded, the size and character of the part, the location of the break, if it is to be welded in place and the cost of doing the work, bearing in mind that the first cost must be considered in the light of the relative qualities of the weld in service. Gas welding, electric welding and thermit welding each have their advantages in their field and are capable of accomplishing some particular operation better than another method.

In railroad work the thermit is almost entirely limited to the welding of engine frames, while the oxy-acetylene and electric arc cover much the same field in the welding of many of the steel parts. No definite limit can be placed on the use of any of these processes where either may be used with success. If equal results can be obtained it is of course desired to use the process with which the work can be performed most economically and to the best advantage. The general run of castings and parts made of cast iron, brass, bronze, aluminum, etc., (non-ferrous class) are welded with the oxy-acetylene process. In cast iron, many heavy sections, however, such as are sometimes encountered in repairs to shop machinery are successfully welded with the thermit process. Other heavy cast iron sections such as cannot be properly preheated for either the oxy-acetylene or thermit process, are repaired by the electric arc process using the usual system of distribution of steel studs about the welded junction.

As is noted above the welding of heavy cast-iron parts may be accomplished with anyone of the three processes. The process selected depending on the outlined conditions. However, generally speaking, where the conditions are favorable for proper preheating

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†Master Welder, Northern Pacific Railway Co.

and execution of the work, the oxy-acetylene process is preferred in the welding of cast iron parts.

In compiling a list of parts on which fusion welding has become standard practice, in the construction and maintenance of locomotives, it is, of course, only possible in a limited space to touch on the major applications and such other applications as are most commonly performed in general routine work in the shops.

The process selected in the welding application on steel parts

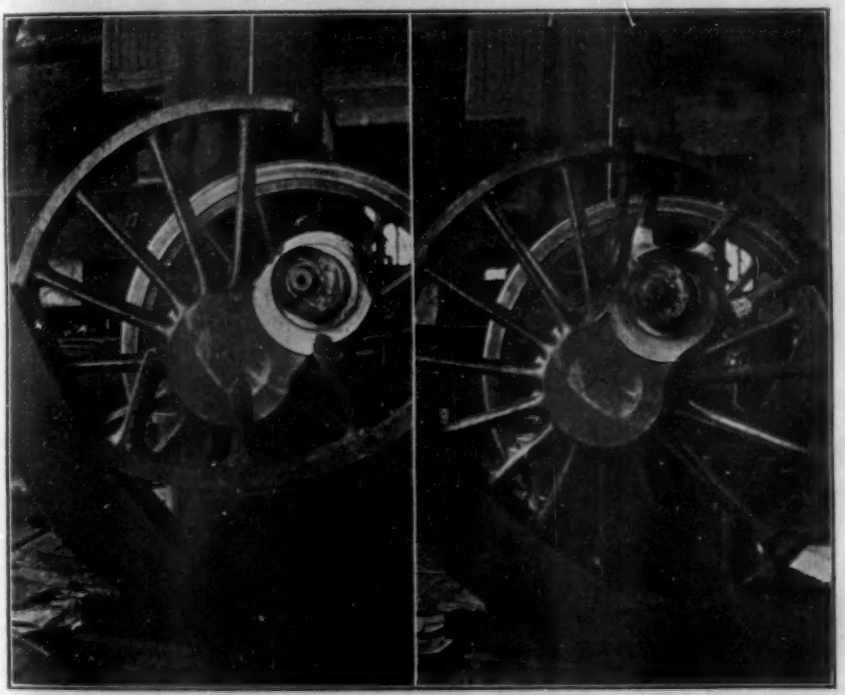

Fig. 1—Broken locomotive drive wheel on left repaired by oxy-acetylene welding as shown on the right. Cost of welding and finishing $24.55. Estimated saving $225.45.

where either the oxy-acetylene or electric arc process may be used will no doubt offer much room for discussion.

It must be borne in mind, however, that all operators are not of the highest skilled type and able to do full justice to the process they represent. The proficiency of the operators, whether it be good or bad, whether it be gas, electric or thermit, many times results in the establishing of practices that are not entirely justified, or based on actual results that could be obtained.

The equipment and facilities with which to perform the work must also be considered, as few railroads are fully or adequately equipped to do their work at all points with all of the three processes to the extent that the lowest figures in economy can be effected. Where equal or satisfactory results can be obtained, the

selection of the process to be used should, of course, be based on the costs of the application.

List of parts covering the most common applications of fusion welding in the construction and maintenance of locomotives:

Locomotive cylinders	Oxyacetylene process
Firebox work, general	Gas or electric (optional)
Motion work (building up worn surfaces)	Electric
Building up locomotive piston heads (mang. bronze)	Gas
Building up air pump piston heads (mang. bronze)	Gas
Building up locomotive guides	Electric (automatic operation)
Building up steel drive wheel centers (diam)	Electric (automatic operation)
Building up trailer wheel centers (diam)	Electric (automatic operation)
Building up steel driving box flanges	Electric (automatic operation)
Welding spokes driving wheel centers (cast iron)	Gas process
Welding spokes trailer wheel centers (cast iron)	Gas process
Welding spokes trailer wheel centers (steel)	Gas or electric
Welding spokes driver wheel centers (steel)	Gas or electric
Building up worn engine truck jaws (cast iron)	Gas
Building up worn engine truck boxes (cast iron)	Gas
Building up broken lugs driving boxes (steel)	Gas or electric
Building up broken lugs driving box cellars (cast iron)	Gas
Welding broken engine truck cellars	Gas
Welding broken tank truck cellars	Gas
Welding broken driving box cellars	Gas
Building up worn cross heads	Gas or electric
Building up broken lugs air brake cylinders	Gas
Building up broken lugs air brake reservoirs	Gas
Repairs to injectors and lubricators	Gas
Welding on grates and ashpan slides	Gas
Building up worn brake beams	Gas or electric
Building up worn equalizers	Gas or electric
Welding on steam pipes	Gas
Welding on nozzle stands	Gas
Welding on air pump cylinders	Gas
Welding and building up on spring saddles	Gas or electric
Welding and building up on engine truck swing links	Gas or electric
Building up lateral main rod brasses	Gas
Welding locomotive frames	Thermit, gas, electric
Welding engine truck frames	Gas or electric
Welding bells	Gas
Building up worn stoker screws	Gas or electric
Welding flues to flue sheet	Electric
Broken mud rings	Gas or electric

Car Work

Bolsters	Gas or electric
Truck sides	Gas or electric
Couplers	Gas or electric
Coupler knuckles	Gas or electric

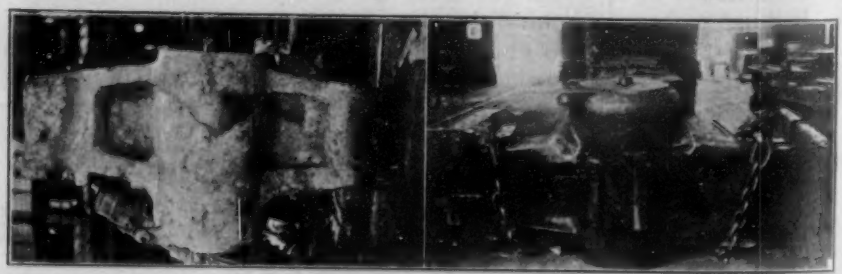

Fig. 2—Cast steel wheel press repaired by electric welding. Total cost of welding and finishing $287. Estimated saving $663.

Axles (end collars).....Gas or electric
Truck pedestals .....Gas
Air reservoirs .....Gas
Center plates .....Gas or electric

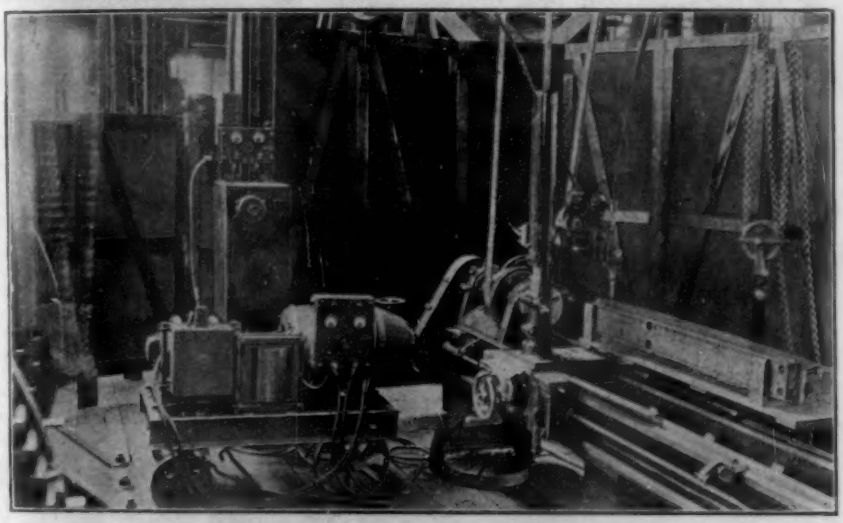

Fig. 3—Building up guides by automatic arc welding

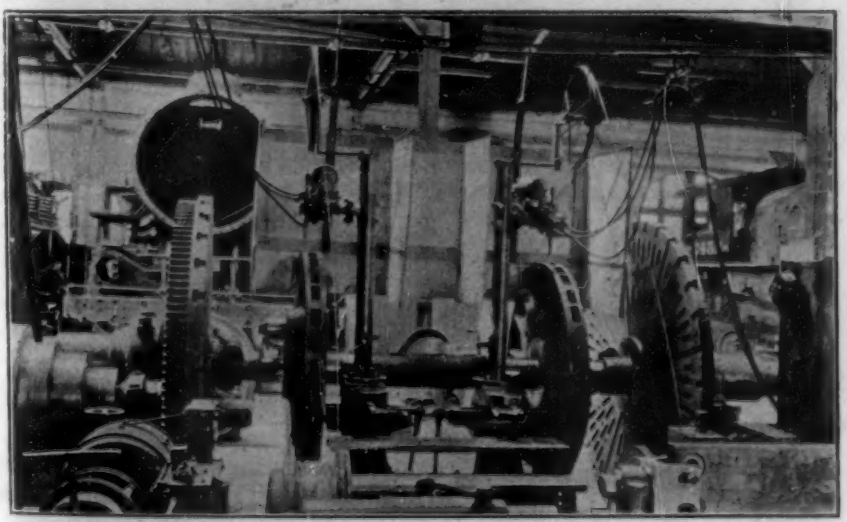

Fig. 4—Building up driving wheel centers by automatic arc welding

In calculating the economies effected by welding, it is necessary to keep extensive records at least for a sufficient period of time to strike a fair average of the varying conditions under which the work comes in and is executed, as well as from the service rendered. The cost of making gas welds, for instance, can be arrived at by checking the time required to do the work, the quantity of gases,

welding rod, etc., used, and the cost of finishing the work after the welding is completed, if further finishing is required.

The cost of making electric welds can be calculated in the same manner, excepting that the electric energy or current used, must be checked instead of the gas which is used with the oxy-acetylene process. The rating of the welding set or tables provided for this purpose may be used in calculating the current used, or this may also be determined by the use of a meter.

With the thermit welds the time is checked, the weight of materials used, etc. In addition to this, in making welds with any of the three processes, it is, of course, necessary to include the cost of preparing the work, such as cutting out the vee, chipping or sandblasting, preheating, annealing, as well as the necessary dis-

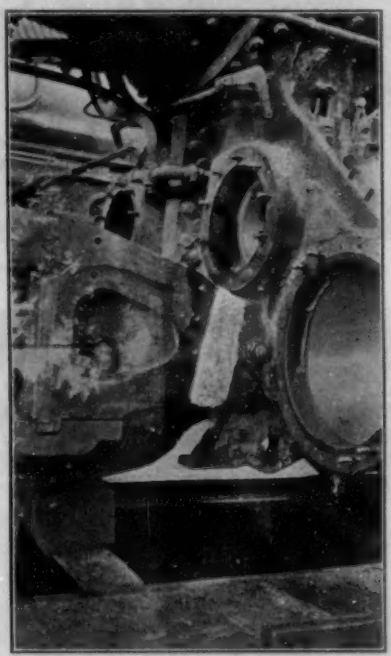

Fig. 5—Repair of locomotive frame by Thermit welding

mantling, etc. Scrap value and overhead should be included.

If, for instance, the repaired job is a casting, it should be given a value rating as compared with a new one, as all reclaimed material cannot be considered to be of the same value as new.

A few examples of savings effected on some of the major operations may be noted following:

	Total Cost New	Total Cost to Weld, Including Overhead	Total Scrap Value	Total Saving
6—drive wheel centers	$1,500.00	$147.31	$90.00	$1,262.69
6—loco. cylinders	5,300.00	740.13	540.00	4,019.87
6—eng. tender bolsters	630.00	124.92	67.30	437.78

In order that the success and economy of the various welding applications may be definitely known, careful and complete records must be kept of all of the sufficiently important operations.

Those responsible for the application and use of the various welding processes must be in a position to know definitely the results in service, in order that the extending and developing of this work may be handled wisely and to best advantage.

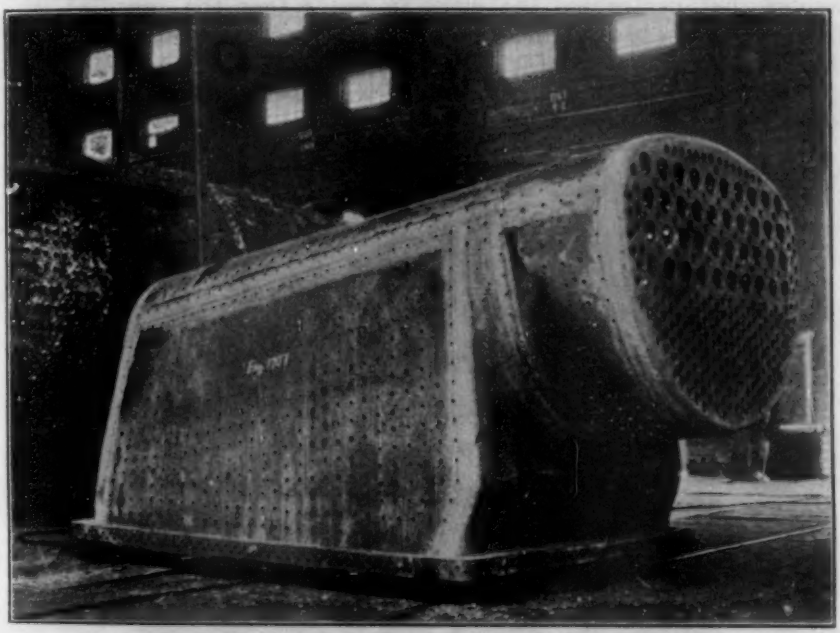

Fig. 6—Fire box completely oxy-acetylene welded

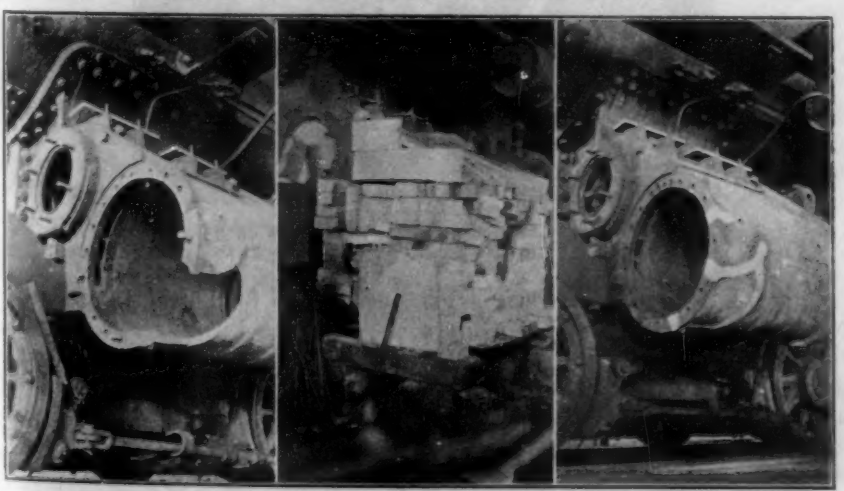

Fig. 7—Broken cylinder repaired by gas welding. Center picture shows method of preheating. Cost of Weld $71 finished. Estimated saving $691

While it would be impossible to keep records of the numerous minor operations performed, yet all of the major and important operations, such as firebox work, locomotive cylinders, frames, car work, etc., should by all means be recorded. Where stamping is practicable, this may be done, showing the date and name of place where weld was made, also the operator's initials or identity.

Failures of welds should be made known to those in charge where the work was performed, and they in turn make it known to the welder that performed the work in order that the cause of the failure may be determined. By careful following up any work that has not given satisfactory results, all concerned will be more on the alert to improve the work. It will likewise make it possible to determine the success of the practice.

Fig. 8—Bells, injectors, switch stands and jacks successfully repaired by gas welding

The inspection of welding must necessarily be largely a matter of observation, both of the operator while he is at work and of the appearance of the weld. Other tests, except in the case of pressure vessels, depend upon the destruction of the weld and are, therefore, inapplicable.

A competent welding instructor or supervisor can readily tell whether an operator is qualified or not to perform the work assigned to him, and none but competent operators should be allowed

to handle important jobs. The ability of welders assigned to do important work should be further ascertained by sample welds submitted to laboratory tests.

Wonderful progress has been made by the railroads in the last few years in the application of the fusion welding processes. However, much still remains to be done before the full economy and value of each individual process can be realized and the work extended to the fullest extent practicable.

The Organization of Welding on the Railroads*

F. H. WILLIAMS†

Generally, for the last few years, throughout the United States and Canada there has been a tendency toward the adoption of electric welding as a standard practice for about 80 per cent of the welding done, the balance of the welding (20 per cent) and the cutting is left to the oxy-acetylene, although there are some places where the electric arc is used for cutting of rivets, plates and cast iron.

Owing to this increasing use of the electric arc as well as the electric current in welding, the Welding Committee of the Association of Railway Electrical Engineers compiled a Manual of Electric Welding and Metal Heating (Instructions and Recommended Practices). It was published in 1926 in loose leaf form.

Its adoption is recommended, especially to railroads who wish to avoid unnecessary experimenting, loss of time and material, and who wish to salvage considerable worn and broken parts of locomotive and car equipment.

The following is a portion of the *"Foreword"* of this Manual:

"The following instructions and recommended practices are for the guidance of those whose duties involve the application of electric welding and metal heating, the object of such instructions being to obtain successful welds and uniform results, insofar as it is humanly possible to do so.

"The instructions are confined to arc welding, spot welding, butt welding, rivet heating, metal furnaces and heat treating, as used in connection with established practices on railroads. This manual to date does not include every job that can be arc welded, but does include many typical jobs that have been and are being successfully performed.

"While it is not practicable to cover all of the many uses to which the processes can be applied successfully, it is felt that with care and adherence to proper methods of application the extent of usefulness of the arts will be practically unlimited. This is dependent

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upon a full understanding of the processes and their application to metals of different character, as well as the service requirements of the parts involved.

"Successful results are dependent upon consideration of these factors together with the exercise of human skill and ingenuity.

"The manual is arranged in sections to facilitate future revisions, these being indexed for convenient reference."

Copies of the manual, described above, may be obtained from Mr. Joseph Andreucetti, secretary of the Association of Railway Electrical Engineers, Electrical Engineer of the Chicago & Northwestern Railway, Terminal Station, Chicago, Ill.

The following is the organization of the welding and the general practice followed on the Canadian National Railways, and for the most part was the practice on most of the American Railroads:

The Organization of the Welding on the C. N. R.

A. Training of operators.
B. Inspection and testing of work.
C. Selection and material for welding.
D. Design of parts to be welded.
E. Organization of supervisory force.
F. Standard instructions for welding.
G. Control of welding method and procedure.
H. Check on service results.
I. Economics.

"A." Training of the Operators

The type of men required for operators who can be depended upon and who are reliable are those who are painstaking, thorough and conscientious; this type of man is preferable to those so-called smart men. A man who has had a fair amount of mechanical training in either the blacksmith's, machinist's or boilermaker's craft should be the man picked to be trained for the respective kind of work he will have to perform.

(*a*) *Training an Electric Welder*

In starting to train a man as an electric welder, he is first taught the principles governing the electric arc. He is then instructed how to start and stop the generator set. Next he goes for several days with an experienced welder to take note of the methods used in welding different parts, following which he is given the electric welding outfit (electrode holder, electrode) connected to a source of supply of proper electric energy and instructed to familiarize himself with the knack of drawing an arc, holding same when struck and taught how to keep the electrode at a steady and proper distance (⅛-in.) from the part being welded and still maintain a steady feed. After he has mastered this he is then instructed to weld a bead following a straight line and shown the meaning of proper penetration by demonstrating the difference between the long and short arc. He is then given beveled plates and shown the way to allow for expansion and contraction, after he has mastered this and shown that he can maintain proper penetration,

he is then given instruction in vertical, horizontal and overhead welding. He is then taught the difference in the electrodes to be used on different classes of metal.

A man's work on what is too commonly looked upon as unimportant work should be carefully watched and he should be taught the importance of what looks like an immaterial job. If an operator takes as much pains in plugging a hole in some minor part of a locomotive or car as the average man would do in welding a frame or boiler you have the best material for a first class operator.

(*b*) *Training An Oxy-Acetylene Welder*

The foregoing article, on the personnel of the electric welder, applies to this process also.

When the workman is selected, he is given the necessary instructions in regard to fitting up his hose and connections where the shops are equipped with pipe line, and where portable outfits are used he is instructed in the proper use and care of oxygen and acetylene regulators. The welder is then instructed in the use of the cutting torch, shown the proper pre-heating flame and as nearly all equipment manufacturers supply, a chart showing the size of nozzle and oxygen pressure required for various thicknesses of plate to be cut, the operator consults this chart until he has them memorized. He is also taught the necessity of using the minimum preheating flame consistent with speed and also the minimum oxygen cutting pressure to use to insure a clean, narrow cut; after the man has become familiar to the operation of the cutting torch and the necessity of always having all acetylene and oxygen hose connections and torches absolutely free from any leakages, he is warned of the explosive properties of acetylene and the inflammable risk that is always present if oxygen gets into contact with oil or grease, also that no lubricant other than glycerine should be used in packing valves, etc.

The welder is then instructed in the use of the welding torch. He is shown how to establish the neutral flame and impressed upon the necessity of this being kept neutral. This is demonstrated to him by having him weld a test piece with each of the three flames, viz.: Neutral, oxidizing and carbonizing flame. He is then instructed in cast iron welding, shown how necessary it is to have the surfaces to be welded perfectly clean, the proper opening to insure perfect accessibility of the flame to the walls of the piece to be welded, the proper lining up and the proper allowance for expansion and contraction. He is taught the necessity and advisability of always preheating all pieces where possible and the absolute necessity of slow cooling to prevent shrinkage cracks. He is shown how to break down the walls of the chamfer and to puddle into the resultant molten metal, his filling rod and the proper use and properties of the flux used. After he has mastered this process, he is instructed in brass welding and brazing, then in the brazing of malleable and gray iron castings.

The welder is then instructed in welding of wrought iron, cast steel, boiler plate and alloy steels.

All men when being instructed should be carefully watched, and when found that on certain metals they show more adaptability on them than others, they should be further developed along that kind of welding if quantity of work permits. In other words, wherever the specializing of the welding can be done, it should.

"B." Inspection and Testing of Work

Welding in the Montreal shops of the Canadian National Railways is under the control of a welding foreman, who is responsible for the work in that line. He oversees all work to be done and the completed work; he inspects work while under way and checks up any improper use of torch or arc. Each welder has to weld one square test bar and one test piece of boiler plate every six months, and great keenness is shown by the operators to beat the other man's work; reports of each test are shown opposite the operator's name and same are posted on the notice boards in the welding shops. These reports show: Tensile strength, yield point, and elongation in 8 in. in plate and 2 in. in test bar.

Also see Appendixes IV, V, VI, VII.

"C." Selection of Material for Welding—See Appendix III.

"E." Organization of Supervising Force

The welding operations in general on the Canadian National Railways, in so far as they concern motive power and car equipment, come under the control of the chief of motive power and the chief of car equipment. Then through the general superintendents of motive power and car equipment down to the superintendents of motive power, or of car equipment, of the various shops as the case may be; then to the shop personnel, as it is best suited to the layout of the shops concerned and the operation of the same.

At the C. N. R. shops, Point St. Charles, Montreal, P. Q., there is a welding foreman in charge of all the welding, assisted by a man who ranks as a charge hand. These two men supervise and are responsible for all the work that is done at the shops at the above named point. There are several service men from the company who supply the gas and materials for the oxy-acetylene welding, who assist and advise regarding that portion of the work. The electrical welding is to a considerable extent under the electrical engineers of the C. N. R.

Research work is done by the assistant engineer of tests, and any failures are reported to him together with pieces of the failed material or parts.

Tensile tests and all chemical analysis is done by Milton Hersey Co., Ltd., consulting engineers and chemists.

Any reports on failed material are made up in triplicate, one copy going to the official sending in the material and one copy is sent to Mr. C. E. Brooks, chief of motive power, Montreal, P. Q. The other copy is kept on file in research laboratory.

"F." Standard Instructions for Welding

These are all embodied in the maintenance regulations, which are included in this paper. See Appendix II.

"G." Control of Welding Methods and Procedure

These also are included herein, in the maintenance regulations. See Appendix II.

"H." Check of Service Results

Records of all frames, cylinders and boiler work that have been welded are kept by the welding foreman, and in case of failure he has the operator's name and where possible a section is cut out and the cause of failure is shown to the welders and they are instructed how to guard against a recurrence of such failure.

Wherever possible, all welded work is examined by the welding foreman when the rolling stock is in the shops for the usual service repairs and the condition of the welds is noted.

All frames and cylinders that have been welded are stamped with shop abbeviation number and the operators' numbers, and a record of this is sent each week to the shop superintendent with the date, engine number, location of break (whether in old weld or a new break), welders' names, class of electrodes or welding wire and remarks.

"I." Economics

The economies effected by thermit, oxy-acetylene and electric welding are very great and numerous.

Engine frames are sometimes welded without even dropping a pair of wheels. The frame is cut out, where broken, with the oxy-acetylene torch, rewelded and put into service again at a cost of less than it would have taken to strip down the frame for a forge weld; taking into account the time saved by placing engine back into service, the cost of bolts, etc., the saving over the old practice is over 100 per cent.

New front end sections are applied by removing leading driver and truck wheels, cutting off old section at center of leading jaw and welding the new section in, thereby saving the removal of the other wheels and frame bolts.

Broken cylinders are repaired in place at a fraction of the original cost of the casting, saving the removal of the saddle, splice and frame bolts.

Motion parts are built up. *Piston heads* are built up where worn with manganese bronze, turned up and put into service again at less than the cost of renewing same. The actual saving being 33⅓ per cent, besides improving the service, the bronze being superior to the cast iron head.

In fact nearly every part of the locomotive is now repaired by one or more of the three recognized processes of welding.

In *boiler repairs* a great saving in money and labor is effected as shown in the following:

Superheater flues are welded in and in good water districts the smaller tubes are also welded into the flue sheet. This saving is

extended to the roundhouses where the time and labor saved is considerable due to the welded-in tubes.

Broken *mud rings* are welded by the simple process of burning out the plate covering the ring, cutting out the crack in the ring, having the vee chipped clean as well as the adjacent edges and then welded, the plate or plates removed are also welded back in place.

Cracks and *patches* are welded in, eliminating the expense of patch bolts and the cost of applying the same.

Half side sheets, crown sheets, tube sheets and back sheets are welded in, eliminating rivets, the punching or drilling of the rivet holes in the flanges; the only rivets being in the foundation ring. By being butt-welded, the double thickness of plate in the fire line is eliminated. The flanges no longer check outwards from the rivet holes. The removal of the stiffness of the double plate allows a more even working of the fire box under the expansion and contraction strains.

Very often the lower half of a back tube sheet is in good condition when the upper half has been condemned. The practice is then to cut out the upper half of the sheet and weld in a new section, thereby saving the renewal of a hundred or more stay bolts and rivets.

Broken *buffer beams* and *back bumping rails* are welded when possible without removing main portion of same.

Steel and *gray iron castings* that have been broken or worn are reclaimed often at a very small fraction of replacing by new castings.

Also see Appendix I.

Conclusion

It would take considerable time and space to enumerate all of the economies in time, money and material that can be effected by the use of thermit, oxy-acetylene and electric welding processes. The actual figures would be very hard to obtain, as working conditions, cost of materials and labor vary in different localities, but under even the most unfavorable conditions, welding, by the above mentioned processes, is a great economic factor in both time and money to any railroad.

APPENDIX I

Economics

These savings are based on American prices at time work was done.

DUPLEX STOKERS

Parts reclaimed by welding. Stoker shaft electric welded

Purchase price, new	$16.40
8 per cent store expense	1.31
	$17.71
Credit for scrap 90 lb. cold rolled at $12.25 per ton.	0.49
Total	$17.22

Reclaiming by welding	
Welding one hour at $1.50	$1.50
Machining to size 1½ hours at 70c	1.05
38 per cent shop expense	0.37
Total	$2.92
Net saving	14.30
Stoker elevator electric welded	
New purchase price	99.00
8 per cent store expense	7.92
	$106.92
Credit for scrap 194 lb. cast steel at $12.25 per ton	1.06
Total	$105.86
Reclaiming by electric welding	
Welding two hours at $1.50	$3.00
Machining to size three hours at 70c	2.10
38 per cent shop expense	0.80
	$5.90
Net saving	99.96

PISTON HEAD

Piston head reclaimed by welding all classes of engine, Class "P." Weight in rough	
500 lb. cast iron at $4.05 cwt	$20.25
7½ per cent store expense	1.52
	$21.77
Machining	
Turn, bore and groove, three hours at 70c	$2.10
Return and fit to cylinder, two hours at 70c	1.40
38 per cent shop expense	1.33
	$4.83
Total	26.60
Scrap 480 lb. C. I. C., $16.96 net ton	4.07
Total, new	$22.53
Reclaiming by acetylene welding	
Labor welding, three hours at $2.50	$7.50
Remachining one hour at 70c	0.70
38 per cent shop expense	0.27
Bronze, 10 lb. used at 46c	4.60
Total	$13.07
Net saving	9.46
Average five piston head per week.	

TENDER TANK AXLES

Tender tank axles welded by electric	
New material, one axle, 5½ x 10 in., 820 lb., at $3.25 cwt.	$26.65
7½ store expense	2.00
	$28.65
Labor, 1½ hours' turning at 70c	1.05
38 per cent shop expense	0.40
	$30.10

Reclaiming by electric welding. Material	
5 lb. S.W., 3/16 in. S.W., at $3.00 cwt	$0.40
9 K.W. current used at 2c. K.W.H	0.18
7½ per cent store expense on 40c	0.03
	$0.61
Labor	
Three hours welding at 75c	$2.25
One hour turning at 70c	0.70
38 per cent shop expense	1.12
	$4.07
	0.61
	$4.68
Credit with 750 lb. of scrap at $10.50 per ton	3.94
Total	$8.62
Net saving	$21.48
Tender tank axles welded by acetylene	
New one axle, 5½ x 10 in., 820 lb. at $3.25 cwt	$26.65
7½ per cent store expense	2.00
	$28.65
Labor, 1½ hours turning to size at 70c	1.05
38 per cent shop expense	0.40
	$30.10
Reclaiming by acetylene welding	
Material, Norway steel, 4 lb. used at 14c. per lb	0.56
Kerosene, two gallons at .074	0.15
Oxygen—acetylene	2.93
7½ per cent store expense	0.27
	$3.91
Labor, preheating ½ at 75c	0.38
Welding, 3 hours at 75c	2.25
Turning to size 1 at 70c	0.70
Shop expense 38 per cent	1 27
	$8.51
Credit 750 lb. scrap at $10.50 per ton	3.94
	$12.45
Net saving	$17.65

AIR PUMPS

Air pumps, one 11-in. air pump cylinder	
Purchase price	$56.13
8 per cent store expense	4.49
	$60.62
Scrap, 200 lb. cast iron, $19.50 per ton	1.80
	$58.82
Reclaiming by acetylene welding	
Preparing for welding, ½ hour at 70c	$0.35
35 per cent shop expense	0.12
	$0.47

Welding and heating, five hours at $2.50	$12.50
Total	$12.97
Net saving	$45.85

BRAKE CYLINDER

Purchase price	$15.24
8 per cent store expense	1.22
	$16.46
Scrap, 115 lb. cast iron, $19 per ton	1.00
	$17.46
Reclaiming by acetylene welding	
Labor, one hour	$2.50
Net saving	$14.96

ENGINE BELL

Weight in rough, 150 lb. brass at 19⅞c	$29.06
Store expense 8 per cent	2.32
	$31.38
Machining, turning 8 hours at 51½c	$4.12
Drill, ½ hr. at 77c	0.39
35 per cent shop expense	1.57
	$6.08
Total	$37.46
Credit for scrap brass at 13⅛c	18.64
Cast new	$18.82
Reclaiming	
Welding 2½ hours at $2.50	$6.25
Turning after welding ½ hour at 51½c	0.26
35 per cent shop expense	0.09
	$6.60
Net saving	$12.22

INSPIRATORS

Purchase price	$81.40
7½ per store expense	6.51
	$87.91
Credit for scrap brass at 14c	4.20
	$83.71
Reclaiming welding by acetylene	
Three hours at $2.50	$7.50
Machining after welding 3½ hours at 70c	2.45
38 per cent shop expense	0.93
	$10.88
Net saving by welding	$72.83

FIRE DOOR PLATE

Purchase price	$14.94
8 per cent store expense	1.20
	$16.14
Scrap, 51 lb. cast iron at $19.50 per ton	0.46
	$15.68

Reclaiming by acetylene welding	
Chipping for welder ½ hour at 70c	$0.35
Welding one hour at $2.50	2.50
35 per cent shop expense	0.12
	$2.97
Total net saving for one plate	12.71

LITTLE END KEYS

Weight in rough	
5 lb. soft steel at $2.45 cwt	$0.12
7½ per cent store expense	0.01
	0.13
Scrap, 3 lb. soft steel at $10.50 per ton	0.02
	$0.11
Machining	
Forge, ¼ hour at $1.17	$0.29
Lay off, 1/3 hour at 70c	0.23
Shaper, 2 hours at 32c	0.64
Turning, 1½ hours at 70c	1.05
Drill, 1/16 hour at 47c	0.08
Fitting up ½ hour at 70c	0.35
38 per cent shop expense	1.00
	$3.75
Reclaiming by electric welding	
Welding ½ hour at $1.50	$0.75
Fit and grind 1¼ hours at 70c	0.87
38 per cent shop expense	0.33
	$1.95
Net saving	1.80

Average 8 per week.

ONE KNUCKLE PIN

Weight in rough	
15 lb. forged iron at $8.53 cwt	$1.28
7½ per cent store expense	0.10
	$1.38
Scrap, 12 lb. at $10.50 per ton	0.06
	$1.32
Machining	
Forge ¼ hour at $2.54	$0.63½
Lay off ½ hour at 70c	0.35
Turn 2¾ hours at 70c	1.92½
Drill ½ hour at 70c	0.35
33 per cent shop expense	1.24
	$5.82
Reclaiming by electric welding	
Welder 1 hour at $1.50	$1.50
Turn 2 hours at 70c	1.40
38 per cent shop expense	0.53
	$3.43
Net saving on one	$2.39

ONE LINK BLOCK

Weight in rough	
10 lb. bolt iron at $5.02 cwt	$0.50
7½ per cent store expense	0.04
	$0.54

Machining	
Forge ¼ hour at $1.17	$0.29
Bore and face 2 hour at 70c	1.40
Drill ½ hour at 47c	0.23
Slot 2½ hour at 70c	1.75
Shop expense 40 per cent	1.47
	$5.68
Scrap 8 in. bolt iron at $10.50 per ton	0.04
	$5.64
Reclaiming by electric welding	
Welding, ½ hour at $1.50	$0.75
Fitting and grinding, 1¼ hour at 70c	0.87
40 per cent shop expense	0.35
	$1.97
Net saving	$3.67

ONE X HEAD PIN

Weight in rough	
62 lb. forged iron at $8.53 cwt	$5.29
7½ per cent store expense	0.40
	$5.69
Scrap, 50 lb. at $10.50 per ton	0.25
	$5.44
Machining	
Forge, ½ hour at $2.54	$1.27
Turning, 5½ hour at 70c	3.85
38 per cent shop expense	1.96
	$7.08
	5.44
	$12.52
Reclaiming by electric welding	
Welding, 1 hour at $1.50	$1.50
Turn, 1½ hour at 70c	1.05
38 per cent shop expense	0.40
	$2.95
Net saving of one pin	$9.57

ONE BRAKE BEAM

Weight in rough	
275 lb. forged iron at $6.91 cwt	$19.00
8 per cent store expense	1.52
	$20.52
Scrap, 225 lb. at $15.10 G.T	1.52
	$19.00
Machining	
Forge, 1½ hour at $2.54	$3.81
Finishing, 2½ hour at $1.17	2.92½
Drill, ¼ hour at 70c	0.17½
Fitting, 2 hour at 39½c	0.79
35 per cent shop expense	3.04
	$10.74
Total	$29.74
Reclaiming by electric welding	
Welding, 2½ hour at $1.50	$3.75
Net saving of one	25.99

ONE ENG TRUCK SWING LINK

Weight in rough	
50 lb. cast steel at $7.18 cwt	$3.59
8 per cent store expense	0.29
	$3.88
Scrap, 47 lb. at $12.25 G.T	0.27
	$3.61
Machining	
Bore, 1 hour at 70c	$0.70
Drill, 1/3 hour at 47c	0.16
38 per cent shop expense	0.33
	1.19
	$4.80
Reclaiming by electric welding	
Weld, ½ hour at $1.50	$0.75
Slot, ½ hour at 70c	0.35
38 per cent shop expense	0.13
	$1.23
Net saving of one	$3.57

Appendix II

MAINTENANCE REGULATION*

Oxy-Acetylene Welding and Cutting

1. *General Instructions:*

Welding on boiler work or on pressure containers of any description must only be done by competent welders who have been thoroughly instructed and have shown by work on test pieces that they can produce a thoroughly homogeneous weld, and have satisfied the foreman or instructor that they are conversant with the principles governing expansion and contraction in welding, and are sufficiently proficient as to be able to detect poor amalgamation of the metal during the process of making the weld.

A properly welded joint should be equally as strong as the plate without reinforcing, or building up in excess of the original thickness of metal, and is preferable in order to obtain ductility and to avoid undue strains due to differing thicknesses of metals.

Poor amalgamation can be detected by the molten metal of the welding rod overlapping the prepared surface of the base metal and running onto the comparatively cooler portions, creating a lamination, and is also to be detected during the cooling of the weld by this not being uniform in color, dark spots developing first where complete union of the metal has not been made.

After any portion of a weld has been made and before such weld is continued, the first portion becomes coated with oxide and slag and it is essential that the termination of the previous portion of

*Editor's Note: These instructions are reproduced from the Standard Loose Leaf Sheets furnished by the Canadian National Railways to show the completeness of such instructions. The drawings referred to are therefore not included by the author.

the weld must be properly prepared for the reception of new metal by heating sufficiently to float off such oxide or slag, which otherwise would be included in the weld.

For the same reason no welding rods must be used that are coated wholly or partially with rust, and any rods found in this condition must be thoroughly cleaned before being used.

Any indication of defects must be taken care of before progressing with the weld by thoroughly floating out the defective portion and refilling with new metal, but in no case must a weld be gone over a second time on the top of the original weld as this sets up stresses with serious after results and is the cause of inclusion of oxide.

In no case must that part of the flame known as the "cone" come in contact with the weld, as the cone consists of unmixed gases and if this touches the weld, it results in inclusion of impurities. The cone must in all cases be held approximately ⅛-in. away from the molten metal.

Welding must only be done when conditions are favorable and no other work such as riveting, tapping or use of air guns must be undertaken while welding is in progress, as the vibration thus caused prevents proper union of the metals.

In welding, the sheets or other parts to be welded must not be in actual contact, a space must in all cases be provided and maintained as laid down in the detailed instructions for the various items of work, and the necessity for such space, which provides for proper penetration, is one of the most important features in connection with a weld.

The preparation of the surface to be welded must also be properly undertaken before actual welding is commenced, all surfaces must be chipped down to the clean metal and no attempt must be made to weld on a torch cut surface.

A vertical weld must in all cases be made from the bottom and worked up to the top and the torch must be held so as to point upward and build up the metal in the V at an angle of 45 deg., in order to provide a suitable angle from which slag may flow and prevent inclusion of the slag in the weld.

Any deviation from a neutral flame, as shown by the shape of the cone, must be instantly detected and rectified, this is usually caused by a defective regulator, and work must be discontinued until the trouble has been remedied.

Before commencing any weld, all equipment and accessories must be checked and every part must be in good order so as to avoid interruptions while the work is in progress.

When work is to be done in the interior of any boiler, tank or other similar inclosed space, an opening must be provided at the top and an air hose attached to an opening at the bottom and a current of air blown through during the whole time that the operator is inside such confined space, in order to insure a supply of fresh air for the operator.

All welding on boiler work must be done with ¼-in. No. 1 High Test Steel.

Cutting must be done with the correct sizes of nozzles as supplied for use with the approved standard cutting torches or blow-pipes, and all operators will be supplied with the maker's charts showing the sizes and pressures to be used for the various thicknesses of metal to be cut.

Cast iron should only be cut with the blow-pipe when it is not possible to part the metal by any other means and when a wide cut ⅝-in. is permissible and the casting will not be injured by local heating. The largest sized cutting nozzle must only be used for cast iron, the smaller sizes being useless for this work.

WELDING RODS AND FLUX

Welding Rods:

Cast Iron Alloy Rods.—To be used in welding gray iron castings.

Iron Wire.—Used generally for welding wrought iron, steel castings, sheet metal, etc. To be replaced by No. 1 High Test Steel with the exception of the ⅛-in. size, when present supply is exhausted.

No. 1 High Test Steel.—Used in welding in boilers, steel castings, locomotive frames, bolsters, truck sides, forgings, etc.

M. W. Steel.—Used in building up frogs, crossings, battered rail ends, also for the welding of tool steel and in building up surfaces where hardness and resistance to abrasion are necessary.

Manganese Bronze Rods.—Used for building up wearing surfaces on piston heads, cross heads, guides, motion work parts and all surfaces subject to friction, unless electric process is used.

No. 10 Bronze Rods (Tobin).—Used in bronze welding cylinders and castings of gray iron, malleable iron, brass and brazing collars to pipes, etc.

Aluminum Alloy Rods.—Used for welding aluminum castings.

Flux:

Ferro Flux.—Used with cast iron alloy rods in the welding of all gray iron castings.

Brazo Flux.—Used with manganese and No. 10 bronze in all building up, bronze welding or brazing operations.

Aluminum Flux.—Used with Aluminum Alloy Rods in welding aluminum castings.

2. *Equipment General:*

All equipment must be of the approved standard type and must be kept in good order at all times.

The use of other than the approved standard type of equipment is prohibited.

Where equipment is supplied under contract, the maintenance of all parts, generators, pipe lines, cylinders, regulators, gages, torches or blow-pipes, hose, etc., will be undertaken by the contractors, and no attempt must be made to repair or tamper with any such parts.

Any defective piece of apparatus must be turned in to the storekeeper or other officer in charge and must be replaced by a spare part.

Complete Welding and Cutting Outfit:

Each regularly assigned operator should be allotted one complete welding and cutting outfit, to consist of the following:

One cutting blow pipe.
One welding blow pipe.
One oxygen regulator. (To operators using portable apparatus only.)
One acetylene regulator. (To operators using portable apparatus only.)
One Prest-O-Lite tank adapter. (To operators using portable apparatus only.)
One 50-ft. length black acetylene hose, 3/8-in. inside diameter, complete with fittings.
One Pyro lighter.
One No. 1 wrench, for blow pipe and regulator connections.
One No. 2 wrench, for regulator and tank connections.
One No. 4 wrench, for welding station connections.
One Prest-O-Lite key, for Prest-O-Lite cylinder valve.
One pair No. 6 goggles, with suitable shade lens.
One pair No. 8 spectacles, with suitable shade lens.
One pair asbestos or leather gloves.
One metal tool box of suitable size. (Equipped with lock.)
And necessary cutting nozzles and welding heads.

3. *Generators for Acetylene:*

Generators are installed only at principal repair points.

When generators are used, the rules in connection with charging and operation of the particular type of generator will be supplied by the maker or contractor and must be framed and displayed in a conspicuous position in the generator house and strictly observed in all particulars.

4. *Safety First Rules:*

The safety first rules in connection with oxy-acetylene welding apparatus are as shown on drawing No. 2H-10377 and prints of these rules must be framed and displayed in a conspicuous position in all shops where apparatus is used, and the attention of shop employees must be drawn to the necessity of proper observance of these rules.

WELDING AND CUTTING IN CONNECTION WITH BOILER WORK

5. *Parts to be Welded:*

Welding on boilers may only be done in fireboxes and on stayed surface.

No welding of any kind is permitted on boiler barrels or any unstayed surfaces of boilers or on any unstayed pressure vessels.

No welding of any description must be undertaken on boilers without authority having first been obtained from the general superintendent of motive power or person authorized by him.

All welding and cutting must be done in accordance with the regulations as shown below.

6. *Cracks in Firebox Sheets:*

Cracks in firebox sheets must be welded when authorized in accordance with the method shown on drawing No. 1H-10354.

Cracks in firebox sheets, which are not over two rows of staybolts in length can be welded successfully and will prolong the life of a sheet but must not be considered a permanent job. The welding of cracks over two rows of staybolts in length is not recommended. Apply a patch in such cases.

Welding rod to be used: No. 1 High Test Steel.

Special Instructions—Remove staybolts which come in line with weld. Heat and bend sheets toward water space, as shown in sketch. Bevel edges including sides of staybolt holes to an angle of 45 deg. Start by welding bottom hole up solid; finish by welding top hole solid. When weld is completely cold, drill, tap and apply staybolts. This does not include cracks in crown sheets.

The advantages of repairing cracks by this method are: 1. The contraction stresses tend to flatten the bent sheets and place the bottom (water side) of the weld in compression. 2. The weld being depressed slightly protects it from the fire.

7. *Side Sheets:*

Half or Full Side Sheets.—Welding rod to be used: No. 1 High Test Steel (¼-in.).

Special Instructions: All sheets to be beveled at an angle of 45 deg. with the cutting blow pipe and the surface of the bevel chipped with an air hammer. Sheets should be fitted up carefully and accurately, allowing not less than ⅛-in. or over 3/16-in. opening at the bottom of the V. Horizontal seams are to be located according to condition of the firebox but not higher than 12 in. below the lowest point of the crown sheet. In instances where the firebox is in good condition near the mud ring it may be cut between the first and second or the second and third rows of staybolts and the new sheet welded to the lower section. All horizontal seams to be located centrally between rows of staybolts.

Small Patches.—In small patches which do not extend to the mud ring, and whose width is not more than three staybolts, a round or elliptical patch with a 1-in. dish should be applied, as per Figure "D" Drawing No. 1H-10353.

Small patches which reach to the mud ring and whose height is not over three rows of staybolts, same can be put in flush providing the patch is cut in half circle, or eliptical shape and the width is not less than twice the height, as shown in Figure "F," Drawing No. 1H-10353. By applying a patch in this method all strains will radiate to the free side.

Large Patches.—Large patches extending to the mud ring should

be made square or rectangular in shape having good rounding corners. The patch should have an O. G. curve placed next to the line of weld, as shown in Figure "E," Drawing No. 1H-10353. The O. G. curve should not extend lower than the top of the grates, as shown by the line A-B on sketch "E" on account of the interference, but should go straight down from where the O. G. leaves off. In order to take care of the contraction in weld A-B and B-D the following procedure is recommended:

Weld either A-C or B-D; then drive a wedge in the center of the patch between the sheet and the mud ring until the sheet leaves the mud ring a distance of at least 5/8-in., then weld the opposite side and quickly remove the wedge. When the weld contracts, the sheet will draw flush to the mud ring and strains will be eliminated.

For large patches which do not extend to the mud ring, same should have an O. G. curve placed next to the line of weld on all four sides, having all four corners rounded with a good big radius. The O. G. curve will not form a mud pocket at the bottom as in the case of a box patch.

8. *Cracked Bridges:*

The method to be used for repair and welding of cracked tube sheet bridges whether front or back or small or superheater flues is as shown on Drawing No. 1H-10350.

Cracked Flue Sheet Bridges.—Cracked flue sheet bridges may be welded by the oxy-acetylene process if the sheet is in fair condition otherwise.

Welding rod to be used: No. 1 High Test Steel.

Special Instructions.—Flues adjacent to the cracked bridges must be removed and the cracked bridge V'd out to an angle of 45 deg. on both sides of the fracture, allowing 1/8-in. opening at the bottom of the V. Allow sheet to become perfectly cold after welding each bridge before starting another.

9. *Knuckle Patches:*

The method of applying and welding knuckle patches to tube sheets or door sheets must be as shown on Drawing No. 2H-10355, Fig. 1.

Where tube or door sheets are riveted, the patches must be riveted to crown or side sheets, and where welded tube or door sheets have been applied, patches must be welded to crown or side sheets and the crown or side sheet must be cut so that the original weld is removed and the new weld must be made to new metal and must only joint the old weld at the ends of the patch.

Back Flue Sheets.—The welding of knuckle cracks in the flue sheet is a temporary job only, and should be explained as such to the foreman in charge before making the weld. In making a knuckle crack weld, same should be welded from the water side of sheet and reinforced on the firebox side.

In making the application of flue sheet patches, the line of weld should run straight across the flue sheet through the thickest section of sheet, as shown on Figure "2," Drawing No. 2H-10355.

Flue holes in the patch falling in line of weld should be left blank. After the weld has been made, these half holes can be cut with the cutting torch and reamed to the proper size. The weld in the flange should run at 45 deg.

In the case of flue sheets where the upper part of the flue sheet needs renewal and the lower section of sheet is in good condition, a new upper sheet can be applied. Welding patches in tube area is prohibited. The line of weld should pass between the row of belly braces and the top row of staybolts. The weld in the flange should run at 45 deg.

Front Flue Sheets.—In the welding of front flue sheets, the line of weld should go straight across the sheet passing through the thickest portion of the sheet, as shown on Drawing No. 2H-10355, Fig. 3, or in other words, similar to the back flue sheet.

If the defective area of the front flue sheet is such that a V shaped patch will take care of it, same can be applied in the V shape, making the line of weld through the smallest portion of the bridge as shown by the line C. in Drawing No. 2H-10355, Fig. 3.

In many cases the front flue sheet is in such a condition that it will have to be removed, and it often happens that in such cases the upper section is in good condition. In a case of this kind a new lower section can be applied, having the line of weld between the top row of the flue holes and the bottom row of boiler braces. This will save removing the boiler braces and also the tee head, etc. The line of weld in the flange should, of course, run at 45 deg.

Back Head.— When cracks develop in back head of boiler, a patch must be applied. (WELDING BACK HEADS IS PROHIBITED.) Back heads may be welded flush and a patch put over the weld.

Superheater Tubes.—Superheater tubes to be welded in consecutive order when new application is being made, as per Drawing No. 3H-10376. Electric process only to be used.

10. *Door Sheets:*

Unless the upper portion of a door sheet is in thoroughly good condition and the arch tube holes have not been enlarged, half or three-quarter door sheets should not be applied but complete new door sheets should be put in.

When new door sheets are applied, the old sheets must be removed complete with the knuckles or flanges; in the case of riveted joints they must be cut out at the line of the outer edge of the rivet holes, and in the case of welded seams, the old side sheet and crown sheet weld must be removed with the door sheet.

If the upper portion of a door sheet is good and a part door sheet application is made, the weld through the knuckle must be at 45 deg. as shown for knuckle patches on Drawing No. 2H-10355, Fig. 1, and the horizontal seam as for side sheets to Drawing No. 1H-10352.

In the welding of half and three-quarter door sheets, a roll should be applied under the line of the weld, the same as used in the case

of side sheets, and shown on 1H-10353. The line of weld across the flange should run at 45 deg.

11. *Fire Door Holes:*

Welded Fire Door Holes.—Fire door holes should be fitted up as though patch bolts were going to be applied, and lap welded as shown at "A" Drawing No. 2H-10355, Fig. 5, or a butt weld may be made as at "B" Drawing No. 2H-10355, Fig. 5.

Door holes having sleeves should also be butt welded.

Welding Door Hole Patches.—In the application of door hole patches, to boxes not equipped with O'Connor fire door hole, an O.G. curve should be placed next to the line of weld, as at "A" Drawing No. 2H-10355, Fig. 4.

The line of weld should be as symmetrical as possible and the symmetrical line should not be sacrificed in order to avoid passing through staybolt holes.

In the case of O'Connor fire door holes, the line of weld should be as symmetrical as possible. There is no necessity of placing an O.G. curve next to the line of weld in O'Connor fire door holes since the curve will take care of contraction, as shown at "B" Drawing No. 2H-10355, Fig. 4.

12. *Fire Door Patches:*

Fire door patches must be large enough to take in at least one row of staybolts all around the door hole, and the outer weld must be made in the same manner as shown on Drawing No. 1H-10352, for longitudinal seams.

13. *Longitudinal Seams in Fire-Boxes:*

When riveted seams for side sheets become defective, the seam must be removed by cutting outside the rows of staybolts above and below the seam.

A patch must then be applied and welded in, in accordance with Drawing No. 1H-10352, and welded also at the ends to the tube and door sheet flange.

14. *Tube Sheets:*

The application of portion of front or back tube sheets is not to be done unless specially authorized, and full tube sheets must be used when repairs are necessary.

The practice as laid down for new door sheets will apply to fire-box tube sheets.

15. *Staybolts:*

When individual staybolts have to be removed, they will be drilled or cut out with the blow pipe.

The flame must be directed onto the center of the head, at fire-box sheet end, into the telltale hole at wrapper sheet end, and held until the bolt reaches a red heat as per Drawing No. 1H-10359.

A cutting jet of oxygen must then be applied and the bolt cut out to a depth of approximately half an inch, Fig. "B" Drawing No. 1H-10359.

The flame must then be held at 45 deg. to pierce the bolt just within the sheet, and when pierced, the blow pipe must be rotated

to carry the cut all around the bolt. Fig. "D," Drawing No. 1H-10359.

When staybolt heads are worn so that they cannot be made tight by reriveting, they must be renewed and NO WELDING IS PERMITTED ON STAYBOLT HEADS.

Removing of Miscellaneous Staybolts.—The removing of staybolts should be made as per Drawing No. 1H-10359. The flame first to be directed on the edge of the telltale hole, Fig. "A," until the metal reaches a red heat, then a cutting jet of oxygen to be gradually applied. Simultaneously move the blow pipe back and rotate the flame so that at a distance of 1¼ in. the full pressure of the oxygen jet is being used, as shown in Fig. "B". After a depth of approximately ½ in. is reached, the flame should be directed at an angle of 45 deg. to bolt, Fig. "C," until the flame pierces the bolt. The torch should then be rotated, completing the portion as shown in Fig. "D".

Rivet Cutting.—The cutting of rivets is recommended.

Care should be taken to use the proper size nozzles for the different sizes of rivets.

16. *Welded Complete Fire-Boxes:*

Instructions.—All sheets should be prepared for welding by beveling at an angle of 45 deg. from the fire side with the cutting blow pipe and the surface of the bevel chipped smooth with an air hammer. All sheets should be fitted up carefully and accurately allowing not less than ⅛ in. or more than 3/16 in. opening at the bottom of the "V". As the flue sheet is usually thicker than the side sheet the two sheets should be flush on the water side.

Horizontal seams should be located centrally between rows of staybolts. All welding is performed on the fire side and reinforced slightly on the water side where possible.

Welding rod to be used—No. 1 High Test Steel (¼ in.).

Welding Fire-boxes on the Floor.—Fire-box sheets should be fit up and held in place temporarily with bolts placed through the mud ring, spacing these bolts 6 in. apart. Next, line sheets up accurately, using clamps if necessary, and tack by welding sections about 1 in. long and about 12 in. apart, starting at the center of the top. The bolts through the mud ring should be 1/16 in. smaller than the holes so the sheets can slip a little on the final contraction. In welding flue and door sheets start at the center or top and work downward to the mud ring otherwise the sheets may bulge or warp at the finishing point.

The reinforcement on the water side should be applied by an operator working about 2 in. behind the operator welding on the fire side.

The longitudinal seams of side and crown sheets of boxes applied in three pieces, in place of one, must be at least 15 in. below the highest point of the crown sheet.

When a weld is started the operator should work continuously and avoid, as much as possible, delays or stops that will allow the weld and sheets to get cold. Do not hammer a fire-box weld.

The flange on both the door and flue sheet should be of the standard form and trimmed to bring the weld on what would be the rivet line between the knuckle and the first row of crown sheet supports.

Welding Fire-boxes in Place.—Similar procedure is to be followed for fire-boxes welded in place, as those welded on the floor, except that all mud ring rivets should be applied and driven before starting to weld.

An O.G. fire-box may be applied in four pieces by cutting off one of the side sheets. The fire-box can then be applied between the mud ring saving the removal of the back head. When the fire-box cannot be applied in four pieces, both side sheets may be cut off and the fire-box applied in five pieces.

Alternative Method.—Welding across the crown sheet between the first and second rows of crown sheet supports.

Similar procedure is to be followed as given, under Welding Fire-boxes on the Floor, or in place, except that the weld is made across the crown sheet between the first and second row of crown sheet stays instead of between the knuckle and the first row of stays.

Alternative Method.—Four piece fire-boxes.

Similar procedure is to be followed as given under:—

Welding Fire-boxes on the Floor, or in Place, with the following additional instructions:

The sheets are prepared then placed in the fire-box through the mud ring and welded in the following order:

1. Side sheet to crown sheet.
2. Side sheets and crown sheet to door sheet.
3. Side sheets and crown sheet to back flue sheet.

To facilitate the handling of the one-piece side sheet and crown sheet the side sheet end is raised while the crown sheet end is lowered and entered sidewise between the mud ring. Then the sheet is moved into position by raising the crown sheet in place.

See Drawing No. 3H-10612.

17. *Mud Ring Corner Patches:*

When mud ring corners require patches, the corners must be cut out in a semi-circular shape, as per Drawing No. 1H-10358, removing as much as necessary from the side sheet and door or tube sheet, to making a complete corner patch, the ends of which must come down to the mud ring at an angle of 45 deg.

The material for corner patches, whether inside or outside must be ½-in. plate.

The patch must be bolted to the mud ring with bolts ⅛ in. smaller in diameter than the mud ring rivet holes and the holes in the patch must be of the same diameter as the bolts.

The patch must be set down so that the bolts rest on the bottom of the mud ring rivet holes, and must be tightened up in this position.

This allows the patch to be pulled up ⅛ in. as the weld contracts.

The edges of the weld to be prepared to standard form V'd to 90 deg. angle with 3/16 in. clearance.

Welding must be commenced at the knuckle and worked both ways along the top of the patch and the sloping portions of the weld at the ends of the patch to be finished down to the mud ring last.

18. *Tubes:*

Superheater tubes must be welded to flue sheets by electric welding, see Maintenance Regulation No. 8, and this work must not be done under any circumstances with oxy-acetylene.

19. *Locomotive Frames:*

Welding Broken Frames.—Broken locomotive frames may be welded by the oxy-acetylene process.

Welding rod to be used: No. 1 High Test Steel (¼ in.).

Special Instructions.—Drop wheels or remove necessary apparatus to enable operators to prepare and make welds properly. Line up frame and mark with rigid tram. Obtain desired expansion with wedge and heavy bar of iron or apparatus made for the purpose. Bevel ends of frame at break at an included angle of approximately 67 deg., with cutting blow pipe, then chip surface clean. Heat ends to a dull red with an oil torch and start welding on both sides simultaneously. Begin at the bottom of the inside of the V and weld to the top, applying a layer of metal about ¾ in. thick on each side of the center. Then commence at the bottom and weld the remaining portions of the frame together, bringing the weld and a 20 per cent reinforcement up at the same time. When weld is completed it should be covered with sheet asbestos or a similar material and allowed to cool slowly. The reinforcement should be from ⅜ in. to ⅝ in. in thickness on each side of the frame, where clearance will permit and should extend 1½ times its thickness beyond edge of the V. Remove expansion apparatus as soon as weld is completed and properly covered with asbestos. The welding of frames from one side only, or by inexperienced operators should not be attempted.

Building Up Worn Frames.—Locomotive frames where worn by driving box saddles, spring hangers, and equalizers may be built to standard dimensions by the oxy-acetylene process, this to include the sides of pedestal jaws, worn by shoe and wedge flanges.

Welding rod to be used: No. 1 High Test Steel (¼ in.).

Special Instructions.—All worn areas, with the exception of lateral wear on pedestal jaws, should be built up with No. 1 High Test Steel and finished to original dimensions with a hammer while the metal is hot. The lateral wear on pedestal jaws should be built up with manganese bronze to within filing limits of standard dimensions. If section to be built up is under compression, heavy bar should be wedged in, in such a way as to avoid frame upsetting while hot. Bar to be removed when building up is completed and section starts to cool down.

20. *Cylinders:*

The entire crack must be beveled to form a 60-deg. V, and the cylinder preheated by lighting a charcoal fire under or in the cyl-

inder or valve chamber as required, and the cylinder warmed up until the oil or grease begins to smoke, and inspection shows that it is uniformly heated and expanded.

Welding must then be commenced, using ¼-in. TOBIN BRONZE welding rods, and the approved BRONZE-BRAZO FLUX.

The temperature of the cylinder must be maintained uniform during the whole time welding is being done.

The V must be brought up to a dull red and coated with flux before the bronze is applied, by dipping the heated end of the welding rod into the receptacle containing the flux.

On commencing to weld, the bronze will flow and "tin" the surface of the cast iron, and this "tinning" must be carried on ahead of the filling in of the V.

On completion of the weld, the cylinder must be cooled slowly, by closing in the space containing charcoal and allowing the fire to die gradually.

21. *Locomotive Cylinder Castings:*

Broken or defective locomotive cylinder and valve chamber castings are to be reclaimed by the oxy-acetylene process, when in a reclaimable condition generally. This to include fractures in barrel, valve chamber, stud flanges, ports, bridges, reinforcement ribs, also steam chest seats and bridges of slide valve type castings.

Welding rod to be used: No. 10 (Tobin) Bronze (¼ in.).

Flux to be used: Brazo.

Special Instructions.—Both sides of the crack or fracture are to be beveled so that the included angle of the bevel is from 60 deg. to 90 deg., the angle decreasing as the thickness of the metal increases, the bevel to extend to the bottom of the crack or fracture. All sand and scale should be removed from ¾ in. to 1 in. on each side of the V on unmachined surfaces. Horizontal breaks on sides of cylinder barrels, etc., to be beveled to an angle of approximately 10 deg. on the lower side of the break and the remainder of the V to be made by increasing the angle on the upper side. On other breaks the bevel on each side to be equal. After broken sections are prepared and fit in place the entire cylinder or valve chamber, or a section thereof, depending on the location of the fracture, should be inclosed in furnace constructed of loose brick, sheet asbestos, or the equal, and preheated slowly to the desired temperature. The weld should be executed as rapidly as possible and when completed cylinder brought to an even temperature then covered up and allowed to remain covered until entirely cold.

22. *Piston Heads and Bull Rings:*

Worn piston heads and bull rings may be built up on the worn surface with MANGANESE BRONZE, see also MAINTENANCE REGULATION No. 29. The surface to be built up must first be ground to reach clean metal and preheating will be done by playing the torch on the half to be welded. Manganese Bronze should be turned 1/16 radius at edge of piston grooves. Under no circumstances should Tobin Bronze be used for this purpose.

23. *Piston Rods:*

When rods are worn in piston or crosshead fits, after being turned on the taper, they will be built up with nickle steel or No. 1 High Test Steel, see also Maintenance Regulation No. 30.

After welding, the rod must be heat treated or where this cannot be done, the welded end must be heated to a cherry red and allowed to cool in lime.

24. *Steel Guide Yokes and Cross Ties, Etc.:*

Broken steel castings such as guide yokes, cross ties, etc., can be welded with ¼-in. nickle steel or No. 1 High Test Steel in the same manner as broken frames, except that no support plates are required under welds, and welds must be made from one side only.

Where circumstances require, or where it is possible to do so, reinforcing to the extent of ⅜ in. may be built up on the top of the weld.

25. *Mud Rings:*

Broken mud rings are to be welded by the oxy-acetylene process without removing. Wasted away areas may also be built up by this process, if the mud ring is in fair condition otherwise.

Welding rod to be used: No. 1 High Test Steel.

Special Instructions.—Light mud rings may be V'd out from one side or the top. Heavy mud rings should be V'd out from both sides or from the top and bottom, the same as locomotive frames.

26. *General:*

Always wear goggles or spectacles when working with a lighted blowpipe. Keep head bands of goggles adjusted so as to hold the goggle securely against the face.

Never heat hollow castings or other objects having inclosed cavities without vent hole.

When working in a confined place be sure there are no leaks in torch or hose and that your helper, or someone familiar with equipment, is on outside to shut off gas supply if necessary.

When welding or cutting in confined space, proper ventilation should be provided.

Never do cutting or welding on an oil barrel or oil container without first carefully removing all oil and vapor. Low pressure steam is a good cleanser. It is a good practice to overflow such containers with water before steaming.

When an operator is welding brasses or bronzes, ventilation is important or the operator wear a suitable respirator.

Never lay cutting or welding blowpipes in superheater tubes, fire-boxes or other confined spaces during lunch hour or when not in use.

Welding and cutting should not be done where there is danger of explosion of coal dust or foreign gases until proper precautions have been taken by a responsible person of the department in which the work is to be done.

Each individual weld on locomotive frames, tender bolsters, car truck bolsters, body bolsters and truck side frames, is to be stamped

as shown below. A record of all such welds, together with the car initials and number or locomotive number, to be kept and forwarded to the office of the Superintendent of Motive Power the first day of each month. Not smaller than ⅜ in. stencils must be used. All rewelded castings must be restenciled and the old stencil marks removed.

Month—Day—Year, thus:—	0-00-00
Shop abbreviation, thus:	A.B.
	C.N.R.
Welder's number:	00

Welding not permitted on unstayed surfaces of locomotive boilers, this to include arch or water bar tubes.

The welding of defective main reservoirs is prohibited.

The welding of fractures or breaks in side rods, main rods, piston rods, eccentric rods or blades is prohibited.

Retaining lips or shoulders of tires must not be removed with the cutting blow pipe.

The building up of work eccentric key ways, set screw recesses or wheel fits on driving axles is prohibited.

Do not cut driver pin holes in the web or plate section of steel wheels.

Welding or building up on cast iron wheels is prohibited.

The welding of grab irons, sill steps, brake wheels or brake staffs is prohibited.

27. *Welding Table:*

WELDING TABLE FOR CONTINUOUS OPERATION

Thickness of Metal	Size of Welding Head or Tip	Oxygen Pressure Lbs. per Sq. In.	Per Hour: Aver. Speed Shop Practice Lin. Ft.	Per Hour: Gas Consumption Oxygen Cu. Ft.	Per Hour: Gas Consumption Acety. Cu. Ft.	Per Lineal Foot Gas Consumption: Oxygen Cu. Ft.	Per Lineal Foot Gas Consumption: Acety. Cu. Ft.	Filling Wire Lbs.
3/16″	6	14	9	15.0	14.2	1.67	1.58	0.08
1/4″	7	16	7	19.2	18.3	2.74	2.62	0.15
3/8″	8	19	4½	27.6	26.3	6.13	5.85	0.3
1/2″	10	21	3	36.0	34.3	12.0	11.4	0.6
3/4″	12	25	1½	52.8	50.4	35.2	33.6	1.4
1″	15	30	1	69.7	66.3	69.7	66.3	2.4

28. *Cutting Table:*

CUTTING TABLE FOR CONTINUOUS OPERATION

Thickness of Metal	Size of Nozzle	Oxygen Pressure Lbs. per Sq. In.	Per Hour: Speed Lin. Ft.	Per Hour: Gas Consumption Oxygen Cu. Ft.	Per Hour: Gas Consumption Acety. Cu. Ft.
1/4″	No. 1	20	139	50.7	17.3
3/8″	No. 2	25	151	108	20.0
1/2″	No. 2	30	130	126	21.7
3/4″	No. 2	35	95	145	23.1
1″	No. 2	40	71	158	24.2
1½″	No. 2	45	45	175	25.0
2″	No. 3	45	46	248	33.0
3″	No. 3	55	36	295	38.5
4″	No. 3	65	26.8	339	42.3
5″	No. 3	75	19	385	44.5
6″	No. 4	75	26.7	542	47.0

ELECTRIC ARC WELDING

1. *General Instructions:*

Arc welding must only be done by competent welders who have been thoroughly instructed and who have shown by work on test pieces that they can produce a thoroughly homogeneous weld, and have satisfied the foreman or instructor that they are conversant with the principles governing expansion and contraction in arc welding, and are sufficiently proficient to be able to detect poor amalgamation of the metal during the process of making the weld or any detrimental variation in the current.

A short arc not more than $\frac{1}{8}$ in. must always be used. Voltage at arc 17 to 20 volts.

2. *Equipment:*

The electric equipment for arc welding may be of any of the various approved types and the manufacturer's instructions applicable to each individual type must be carefully observed.

The current for welding may be direct or alternating current.

In all cases the amount of current is regulated by the rheostat and operators must be thoroughly instructed as to the operation of this device and in starting and stopping motors, and the general operation of the equipment.

3. *Accessories:*

All accessories for arc welding must be kept in good order.

(a) *Mask and Face Shields.*—A mask with standard glasses to protect the eyes will be issued to each operator for his individual use, and he will be held responsible for proper care of the same. Masks must always be worn when welding is being done.

(b) *Gloves.*—Leather gloves should be worn when welding to protect the hands.

(c) *Portable Screens.*—When welding is being done, portable screens must be used to protect other employees from the glare of the arc.

(d) *Welding Cables.*—Standard welding cables only must be used; together with a special flexible lead equipped with tongs for holding the electrode. When the insulation on cables or leads shows signs of wear, these must be properly repaired by the electrical department.

(e) *Wire Brushes.*—A wire brush will be issued to each operator, with which all the surfaces of material to be welded must be cleaned, and also to be used between each layer of deposited metal to remove oxides.

4. *Parts to be Welded:*

Arc welding must be used for the classes of work shown below, and this table shows the current and voltage required under favorable conditions and should be used only as a general guide.

ELECTRODE

(Manufacturer's name and number of rod is also included.)

Diam. in Inches	Class of Work	Amperage	Arc Voltage
1/8″	Welding boiler tubes to flue sheets.....	100–110	14–16
5/32″	Building up side rod ends, guide bars, motion parts, axle boxes, etc.....	120–130	16–18
5/32″ or 3/16″	Heavy castings	125–150	18–20
3/16″	Welding worn part on locomotive frames....	120–130	18–20
3/16″	Locomotive frames. (See Paragraph 8, "Welding Loco. Frames").....	120–130	18–20

5. *Preparing Welds:*

Before welding is commenced, the joint must be properly V'd out, and a clearance of 1/8 in. left between the parts. The metal must be chipped or brushed clean, and if beveling has been done with an oxy-acetylene torch, the surface must be chipped down to bare metal to remove slag or oxide.

Expansion and contraction must also be provided for.

6. *Welding Superheater Flues:*

The method of setting and welding superheater flues to fire-box tube sheets is as shown on Drawing 3H-15173, and details shown on this drawing must be carefully observed.

7. *Building Up Worn Surfaces:*

After wearing parts of locomotive frames, side rods, guide bar faces, motion parts, axle boxes, etc., are worn below the permissible limits shown on the Maintenance Regulation covering the various parts, one layer of metal must be welded on, the thickness to be sufficient only to restore the part to its original size with the minimum amount of grinding or machining. Brake hanger pins must not be built up by welding.

8. *Welding Locomotive Frames:*

After the fracture has been V'd out to 30 or 45 deg. by oxy-acetylene torch, the coating of blue oxide must be removed, otherwise it will be difficult to establish an arc.

Two operators are required for frame welding; once a weld is started it must be completed without delay, if necessary the welders being replaced by relief men. After the points of the bevels have been fused together, operators should deposit metal on each side of the frame as shown on "C," Drawing No. 3H-10357. When space will permit, the frame should be reinforced, applying 3/8 in. additional metal to top and sides of weld as per Drawing No. 3H-10357.

9. *Record of Frame Welding:*

When locomotive frames are welded a record must be kept by shop superintendent as per Drawing No. 3H-10357.

10. *Strength of Weld:*

After the new operator has had the usual preliminary training, he will at various times be required to submit standard test pieces as per Fig. 6, Drawing 3H-10357, which will in turn be submitted to the engineer in charge of tests, and the results obtained from these tests, which should show an average tensile strength of 40,000

lb. per sq. in., will determine the proficiency of the operator, and his promotion to more responsible duties will be governed accordingly.

Arc Length.—It is very important that operators endeavor to maintain a short arc as the oxygen and nitrogen of the atmosphere have a detrimental effect on the metal being added. Therefore, if arc length is excessive, the effect of the atmosphere will be increased accordingly. Proper and improper arc length. See Paragraph 4 of this regulation.

APPENDIX III

SPECIFICATIONS

For Electrodes for Electric Welding

(Conforming to report to the American Bureau of Welding of the Committee on Welding Wire).

1. This specification covers wire for use in electric welding; to be used for various purposes as follows:

Low Carbon

(a) For welding mild steel, structural shape plates bars or low carbon steel forgings and castings. Use grades E No. 1-B, E No. 2-B, E No. 1-C, E No. 2-C, E No. 3-B, E No. 3-C.

Medium Carbon

(b) For building up worn surfaces that require machine finish, such as wheel flanges, axle collars, etc. Use grade E No. 4-C.

High Carbon

(c) For welding high carbon steel and worn surfaces where great resistance to abrasive wear is desired and where machining is not necessary, such as rails, frogs, switch-points, bearing surfaces, etc. Use grades E No. 5-C, E No. 6-B, E No. 6-C.

Manganese Steel

(d) For use on manganese crossing centers, frogs, switch-points, dredging buckets and other parts where extremely hard, tough surface is required. Use grade E No. 7-C.

2. *General Requirements*

The electrodes shall be subject to factory inspection, chemical analysis and physical tests.

In the hands of an experienced welder they shall demonstrate good weldability (in flat and overhead positions in the case of electric welding) and shall flow smoothly and evenly without any unusual characteristics.

All purchasing orders for welding materials shall refer to the particular specification or grade under which the material is being bought and when shipment is made, all specification numbers or grades shall be marked on all packages in a similar manner. The specification number shall always include the prefix letter "E" denoting that the material is for electric welding. It shall also include the suffix letter "B" or "C" indicating bare or coated wire.

3. *Material*

Material made by the puddling process is not allowed.

4. *Physical Properties.*

(a) Electrodes shall be made from straight wire of uniform homogeneous structure free from irregularities in surface hardness, segregations, oxides, other non-metallic inclusions, pipes, seams, etc. The surface shall be free from scale and rust, oil or grease, except that resulting from the last drawing operation.

(b) All alloy rods shall be straight, and of homogeneous structure. The surface shall be smooth and clean.

(c) The diameter of all wire except cast iron shall not vary more than plus or minus 3 per cent from the diameter specified.

5. *Tests.*

(a) One chemical analysis shall be made for each 1000 lb. or less, and in addition one welding test for each 1000 lb. shall be made by a competent operator to determine satisfactory welding qualities.

(b) The inspector or representative of the railways shall be privileged to make tensile and bend tests in same ratio should he so desire, with the exception of the low carbon wire, on tensile test the wire shall not show more than 5 per cent elongation in 10 in.

(c) Check chemical analysis may be made by the inspector or representative of the railways and without cost to the contractor. The chemical composition thus determined shall conform to the requirements specified in the tables for the grade ordered.

(d) If a check analysis is made, a composite sample of not less than 4 oz. shall be taken for analysis from each 1000 lb. or less. At least one wire from every size in each 1000 lb. or less shall be selected. Where the 1000 lb. or less consists of but one size, one wire from each of five bundles shall be selected. Samples shall consist of fine particles obtained by clipping, sawing, or drilling, depending on the size of the wire.

6. *Packing and Marking.*

Electrodes shall be delivered in coils or in straight 14-in. or 18-in. lengths, and shall be packed and wrapped as follows:

(a) Bundles of 50 lb. net weight, securely wired and wrapped in heavy weatherproof paper.

(b) Bundles of 50 lb. net weight, securely wrapped in heavy burlap.

(c) Boxes or kegs of 100, 200 or 300 lb. net weight and wrapped as per paragraph (a) or (b).

(d) Coils of approximately 50 or 100 lb. net weight, and wrapped as per paragraph (a) or (b).

All bundles, coils, boxes or kegs shall be provided with a metal, linen, or strong fiber tag securely wired to or in the case of boxes or kegs, nailed on the outside, bearing the following information:

Make .....
Grade .....
Diameter .....
Nominal weight .....

7. The wire shall conform to the following:

Grade or Specification	C. Per Cent	Mn. Per Cent	P. Per Cent Max.	S. Per Cent Max.	Si. Per Cent Max.	Sizes of Wire
Low Carbon						
E No. 1-B or C..	0.06	0.15	0.04	0.04	0.08	1/8", 5/32", 3/16", 1/4"
E No. 2-B or C..	0.08 to 0.14	0.35 to 0.50	0.04	0.04	0.08	1/8", 5/32", 3/16", 1/4"
E No. 3-B or C..	0.13 to 0.18	0.40 to 0.60	0.04	0.04	0.08	1/8", 5/32", 3/16", 1/4"
Medium Carbon						
E No. 4-C.....	0.25 to 0.45	0.30 to 0.60	0.04	0.04	0.12	1/8", 5/32", 3/16", 1/4"
High Carbon						
E No. 5-C.....	0.60 to 0.75	0.60 to 0.90	0.04	0.04	0.12	1/8", 5/32", 3/16", 1/4"
E No. 6-B or C..	0.85 to 1.10	0.30 to 0.60	0.04	0.04		1/8", 5/32", 3/16", 1/4"
Manganese						
E No. 7-C.....	1.10 to 1.35	11.00 to 14.00	0.017 to 0.050	0.017 to 0.050	0.10 to 0.20	1/8", 5/32", 3/16", 1/4"

8. *Inspection.*

Unless otherwise shown on purchasing order, welding wire will be inspected at destination. If so desired or ordered, the wire may be inspected before shipment and in such case the manufacturer shall furnish free of charge all reasonable facilities for the inspection to be properly carried out.

9. *Rejection.*

In case of rejection at destination, the manufacturer shall pay freight charges both ways on shipment.

C. E. BROOKS,
Chief of Motive Power.

Issued—July, 1925.

APPENDIX IV

Tests—Mild Steel Bars, Double-Vee Welded, at the Various Round-Houses—Oxy-Acetylene

Number of Round House	Tensile Strength, Lb. per Sq. In.	Elastic Limit, Lb. per Sq. In.	Elongation in 2 In. Per Cent
Danforth No. 1	52,800	24,650	19.0
Stratford No. 3	46,850	17,860	19.0
Palmerston No. 4	16,300	9,420	6.0
Hamilton No. 5	42,220	20,500	28.0
Niagara No. 6	33,910	24,260	7.0
Fort Erie No. 7	48,800	23,800	12.0
St. Thomas No. 8	35,500	22,480	9.0
Sarnia No. 9	50,550	26,100	22.5
Toronto No. 1	38,200	22,670	5.0
Toronto No. 11	44,730	26,600	15.0
Mimico No. 12	58,600	10,020	31.0
London No. 13	47,740	29,420	22.5
Allandale No. 14	53,570	31,200	18.0

APPENDIX V

Tests—½-in. Plates Welded by Operators at the Various Round-Houses—Oxy-Acetylene

Number of Round House	Tensile Strength, Lb. per Sq. In.	Elastic Limit, Lb. per Sq. In.	Elongation in 8 In. Per Cent
Danforth No. 1	60,320	35,120	7.0
Windsor No. 2	53,560	37,900	6.3
Stratford No. 3	54,600	36,100	9.4
Palmerston No. 4	41,670	36,410	1.6
Hamilton No. 5	53,460	39,600	4.8
Niagara No. 6	35,900	35,900	1.6
Fort Erie No. 7	56,930	35,400	11.0
St. Thomas No. 8	50,530	39,800	3.9
Sarnia No. 9	58,720	35,700	12.5

APPENDIX VI

Tests—Mild Steel Bars—Double-Vee Welded At "A" Shops

By Oxy-Acetylene and Electric Welding

Welder No.	Tensile Strength, Lb. per Sq. In.	Elastic Limit, Lb. per Sq. In.	Elongation in 2 In. Per Cent	Process, and Rod.
No. 1	51,024	51,024	3.5	Electric
No. 2	60,200	39,800	5.5	Electric
No. 3	58,200	42,350	5.5	Electric
No. 4	49,200	39,030	4.0	Electric
No. 5	42,600	42,600	2.5	Gas
No. 6	37,100	37,100	2.5	Gas
No. 7	30,870	30,870	4.0	Gas
No. 8	68,500	36,840	15.0	Gas
No. 9	49,750	39,100	6.0	Electric
No. 10	45,920	31,120	5.0	Gas
No. 11	62,100	50,640	9.0	Gas
No. 12	52,000	36,670	7.0	Electric
No. 14	62,760	38,010	9.0	Gas
No. 15	64,300	41,840	8.0	Gas
No. 16	53,600	53,600	5.0	Electric
No. 17	61,735	33,300	30.0	Gas
No. 18	22,550	22,550	2.5	Electric
No. 19	53,675	39,300	5.0	Electric
No. 20	58,300	32,750	7.0	Electric
No. 21	55,630	41,630	6.0	Electric
No. 22	63,400	35,100	9.0	Electric
No. 23	35,970	35,970	3.0	Electric
No. 24	43,460	43,460	3.0	Electric
No. 25	64,030	34,700	10.0	Gas
No. 26	60,540	45,660	7.0	Gas
No. 27	52,430	35,760	10.0	Gas
No. 28	61,220	42,990	7.0	Gas
No. 29	48,340	48,340	4.0	Gas
No. 30	35,715	31,900	4.0	Gas
No. 31	47,450	37,860	2.5	Gas
No. 32	43,400	43,400	2.5	Gas
Original	105,100	93,860	7.0	

Fracture, coarse grain due to over heating in rolling.

Note.—Test bars were made of 1⅛″ bar welded double-vee and turned to standard ½″ test piece.

Note.—No. 17 broke outside the weld.

APPENDIX VII

Tests on Boiler Plate Welds at "A" Shops by Oxy-Acetylene and Electric Welding

Welder No.	Tensile Strength, Lb. per Sq. In.	Elastic Limit, Lb. per Sq. In.	Elongation in 8 In. Per Cent	Process, and Rod
No. 1	36,940	27,555	3.1	Electric
No. 2	48,360	37,870	9.4	Electric
No. 3	41,385	30,170	6.25	Electric
No. 4	46,645	28,570	7.8	Electric
No. 5	51,985	20,710	21.8	Gas
No. 6	49,495	28,450	11.0	Gas
No. 7	49,580	26,800	25.0	Gas
No. 8	52,000	31,260	12.5	Gas
No. 9	35,970	27,005	4.75	Electric
No. 10	48,630	28,600	11.75	Gas
No. 11	50,000	26,868	26.6	Gas
No. 12	47,500	31,370	7.5	Electric
No. 14	53,910	32,220	21.75	Gas
No. 15	52,828	30,845	23.5	Gas
No. 16	49,150	28,460	12.5	Electric
No. 17	36,320	28,000	3.10	Gas
No. 18	46,240	27,060	23.5	Electric
No. 19	47,500	29,500	7.75	Electric
No. 20	37,310	31,480	3.1	Electric
No. 21	45,180	27,710	7.75	Electric
No. 22	44,200	30,840	4.75	Electric
No. 23	42,800	29,730	6.25	Electric
No. 24	45,940	29,780	7.75	Electric
No. 25	52,710	30,050	21.0	Gas
No. 26	56,325	32,990	25.0	Gas
No. 27	54,410	30,600	22.6	Gas
No. 28	48,900	29,150	19.9	Gas
No. 29	50,200	28,300	15.3	Gas
No. 30	53,770	31,900	21.1	Gas
No. 31	48,570	28,140	20.6	Gas
No. 32	49,860	29,860	21.9	Gas
Original	56,840	32,800	23 5	

Nos. 11, 14, 15 and 18 broke outside the weld.

Tests on Oxy-Acetylene Welded Roof Trusses†

H. H. Moss*

During the months of April and May of this year, a series of tests was conducted at the Buffalo shops of our company, on some oxy-acetylene welded steel roof trusses. These tests were preceded by studies of this problem during several years. A practical and sound method for fabricating structural steel by oxy-acetylene welding was sought and constructive results have now been obtained.

For the past three or four years our company has witnessed the construction of and been confronted with numerous calls in connection with the welded fabrication and repair of highway bridges, foot bridges, garage, warehouse and pump-house buildings, tank towers and many other minor structures, utilizing everything from new or second-hand pipe to structural plates and shapes. Such

†To be presented at the Fall Meeting of the A. W. S., Buffalo, November, 1926.

*The Linde Air Products Co.

incidents doubtless are manifestations of what may be termed the normal development of the process in the hands of the practical welder. Sound engineering principles were often disregarded, in fact, engineering analysis was frequently lacking and the results obtained, while commendable, varied greatly in detail and could not be satisfactorily interpreted from a rational standpoint.

As a basis for initial study one of the company's standard building structures was selected; the design of the details could be experimented with in the laboratories; furthermore we could build the trusses and place them into a new building, thus translating preliminary studies into practical service. This structure provided a one-story building, with roof of 40-ft. span having the usual one-quarter pitch roof without monitors.

Initial studies produced what has been termed "insert plate joint." It was developed while trying to place web metal concentrically around center lines in a theoretical diagram and by adding long steel rectangles on either side of this web metal to obtain sufficient area and rigidness for a practical structure.

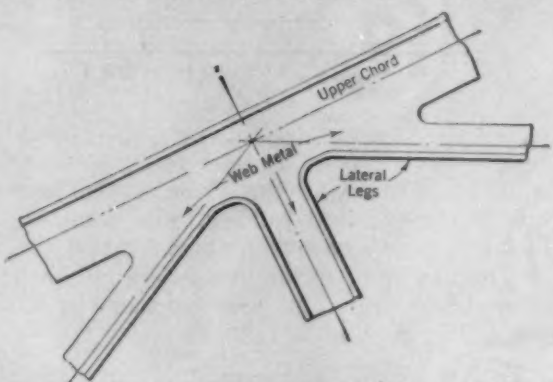

Fig. 1. Ideal Joint Between I-Beam Sections

Angles, tees, and tubular sections were tried with this idea as a basis for joint design. For each shape an elementary truss design was studied, thus determining the style of the joints that must be developed to complete a truss structure. An ideal joint is shown in Fig. 1.

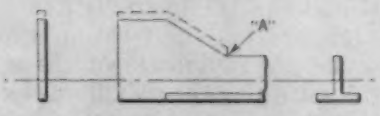

Fig. 2. Study of a Joint Between Structural Shape and Gusset Plate

The next and obvious problem consisted of transferring the full strength of members having lateral metal into the web plate or into a single flat plate somewhat as shown in Fig. 2.

This sketch suggested the insert plate design. While the intended scope of this article does not permit a full account of this

development (nor, indeed, can this be correctly defined until further investigations are made) a typical application as used in this test series is illustrated in Fig. 3.

It will be observed that a portion of the leg of members a, b, and c, has been removed. An insert plate, fashioned as shown, d, e, f, g, h, m, placed in the planes of the longitudinal legs of the tee-shaped members, a, b, and c, supplies the necessary metal for trans-

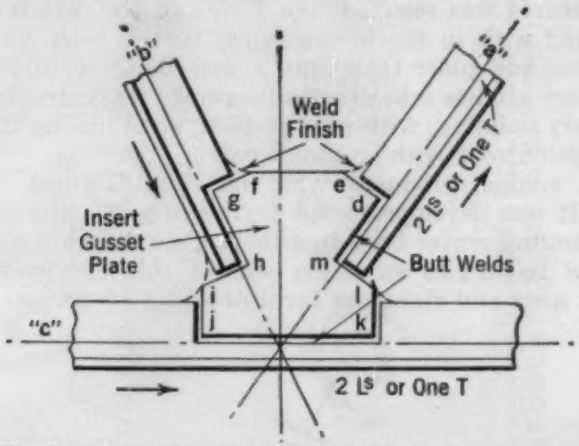

Fig. 3. Typical Plate Insert Joint for Angle Iron Sections

fer of stress at the joint. Union of these several parts was accomplished by oxy-acetylene butt-welding where metal joined metal, the result being a homogeneous plane of metal transferring the applied forces by means of welds in tension and shear in members a and c, and in compression and shear in member b. Briefly, such a design provides several advantages:

1st—Center of gravity lines of the members converge exactly at the true intersection points.
2nd—All principal welds are placed at or very near to the center of gravity of the member joined.
3rd—The major portion of the welds function in shear.
4th—All metal is joined with butt welds.
5th—All metal joined may be placed symmetrically in regard to the axial plane of the main structure.
6th—A non-rigid weld at the terminal of each member.
7th—Easy means for rounding out the weld ends or filleting the finish (as shown by the dotted lines in Fig. 3) thus avoiding abrupt angles.

Preliminary Work

First, a series of tests was conducted in our laboratories in Long Island City, on typical joints. Specimens were set up in correct fixtures in a 100,000-lb. Olsen tensile machine and pulled to rupture. In each the base metal of the adjoined member failed, at

some distance from the tension weld in the insert plate—an evidence of the strength of this type of joint. Unit tensile strength developed in these tests averaged 56,000 to 57,000 lb. per sq. in., or approximately the average maximum strength of rolled shapes. There was no distress noticeable in the welds at the time of failure of these specimens. The material used was standard angles bought from a local warehouse. The filler rod or deposited metal was

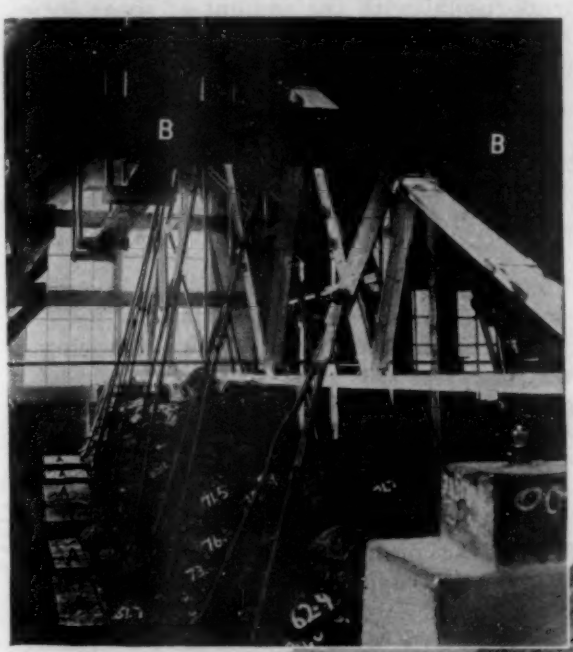

Fig. 4—General view of testing arrangement

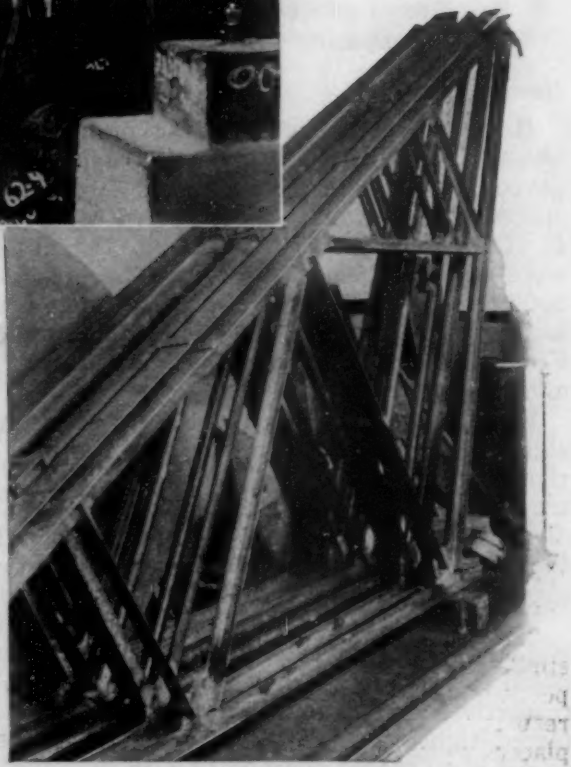

Fig. 5—Plate insert trusses

a special high test rod, the quality of which develops the full strength of the base metal across properly made butt-weld in mild steel.

These results proved that by using proper filler rod material the strength of the out-board legs of a member could be transferred into the insert plate. The assumptions for the plate design consisted of adding plate metal from the point of origin of transfer (point a, in Fig. 2) proportional with the amount of shear increment transfer along the shear leg of the weld. An arbitrary additional amount of approximately ½ in. was made to this width, as shown dotted in Fig. 2, to insure of ample strength. At the present time the straight-line principle of metal (or stress) transfer is being used, subject to modification as our experiments on this detail progresses.

Among others, the unknown factors remaining in the problem consisted of:

1st—Proving the efficiency of the insert plate design in a practical structure and under shop conditions of welding.
2nd—Determining the feasibility of the design embracing a complete truss structure.
3rd—Determining how the residual stresses due to welding (if any) affect a truss structure.
4th—Comparing the cost with riveted construction.

Design

Having as a background the preliminary insert plate design and the results of the specimen tests, complete designs were prepared for a series of trusses of 40-ft. span, one-quarter pitch, spaced 15 ft. center to center, to withstand a load of 40 lb. per sq. ft. of horizontal projection. Due to the method of testing, all loads were disposed vertically at each panel point and summed up to 3000 lb. per panel, there being seven panel points of concentrated loading not including those immediately above the end supports. From these loads the working stress for each member was determined.

For comparison it was necessary to study a riveted truss, designed and built from the same specification. Both design and fabrication were done by a reputable concern, which furnished the truss material for both the riveted truss (Case 2 below) and its direct competitor (Case 3) all of which material was secured from the same rolling, and the physical properties of which were recorded. The yield point of this steel averaged 40,000 lb. per sq. in.

The several trusses, with the exception of the tubular one, were similar with respect to the upper and lower chords, being composed of two 3 x 2½ x ¼-in. angles and two 2 x 2 x ¼-in. angles respectively. The top chord angles of the welded trusses were placed tightly back to back, whereas in the riveted truss these angles were spaced apart ¼ to 5/16 in.

Case 1—Welded—Preliminary test truss. This truss had an identical member design as Case 4, with the exception that the main strut was made of two 3 x 2½ x 5/16 tees. This truss was welded in quarters, then in halves each (side of the ridge joint). Afterward field joints were made at peak at a third point in the lower chord. Gusset plates: ½ in., made up to two quarter-inch plates.

Case 2—Riveted—Main web diagonals from ridge to field splice at lower chord; two 2 x 2 x ¼-in. angles. Main web strut; two 2½ x 2 x ¼-in. angles. Sub-strut: one 2 x 2 x ¼-in. angle. Sub-tensional diagonal: one 2 x 2 x ¼-in. angle. Gusset plates: ¼ in. and 5/16 in.

Case 3—Welded—The same composition and disposition of angle-iron members. Gusset plates ½ in., made up of two ¼-in. plates, each welded into the ¼-in. legs of each member at a joint.

Case 4—Welded—The same composition as Case 2, with the exception that the main web tension diagonals were two 1½ x 1½ x ¼-in. angles. Sub-struts and sub-tensional diagonals: two 1½ x 1½ x ¼-in. angles.

Case 5 — Welded — Tubular Sections. Upper chord: 3-in. nominal size standard black pipe. Lower chord: 2½ in. Main strut: 2½. Main tension diagonals: 2 in. Remaining web members: 1½ in.

Welding Procedure

The first item under this heading consisted of testing the welders. The welders selected for this work were required to make welds in structural steel developing a minimum tensile strength of 50,000 lb. per sq. in. in a standard American Welding Society tensile coupons. The actual results obtained from these coupons using high test filler rod averaged 60,000 lb. per sq. in.

The welding procedure, governing Cases 3, 4 and 5, consisted of first, welding the insert gusset plates into the principal truss members, after which these members were straightened where necessary, by the aid of a heating torch. Next, the partially welded members and the remaining web members were assembled into the truss form, clamped together and tack welded. By the aid of a cardboard angle template, proper alignment of the truss was maintained. The final welding progressed from this point. This procedure proved to be the most practical and was adopted after experimenting with several procedures with Case 1. Due to the use of two 1¼-in. insert plates at each joint, double "V" welding was approached as each truss half after being welded throughout on one side was turned over and again welded on the opposite side.

The Test Structure

The available floor space in the Buffalo shop provided a width of 12 ft., and a length of 60 ft., within which the testing equipment

was erected. The photograph (Fig. 4) shows the general view of this arrangement. The hanging platforms A for loading, purlin construction B for holding panel points laterally, to 8 x 8-in. timber gantries are clearly shown. The trusses under test were supported at either end by concrete piers, one providing for rigid anchorage, the other with a set of rollers and a rocker casting placed between bearing plates. Approximately 40 tons of pig iron was accurately weighed for this test, each pig having its correct weight painted on in white numerals.

Test Procedure

The trusses after being erected were carefully lined up by means of plumb-bobs suspended from a true line above. Eight-inch channel purline secured the top member laterally. Freedom to move in a vertical plane was accomplished by means of slip plates on the gantries. Two ¾-in. round adjustable rods secured the lower chord against lateral movement. The suspended platforms were carefully leveled before each test by aid of the turn-buckles. Truss deflection was measured against a tightly drawn steel wire secured to the gusset plates at either end of the truss. Uniform loading was obtained by adding a pig consecutively to each platform. Deflection readings and stress investigations were taken at panel loads of 3000 lb., 6000 lb., 9000 lb., 10,000 lb. Above 10,000 lb. load was added 70 lb. at a time (the average weight of one pig) up to point of failure.

Strain Gage Work

Strain gage readings were taken on both sides of each member of each truss for the purpose of determining the effect of residual welding stress in such a structure, and to study its elastic action. Gage readings were very carefully taken at each station at the following load conditions:

1st—Dead truss weight including weight of the purlins and hangers but without the platform weight.
2nd—With platform weight added.
3rd—At 3000 lb. per panel, the design load.
4th—At 6000 lb. per panel.
5th—At 9000 lb. per panel.
6th—At 10,000 lb. per panel.

The fifth and sixth readings could not be made for the riveted and tubular trusses, because they reached their ultimate strength slightly below 9000 lb. per panel.

Stress as determined by the strain gage agreed very closely with the theoretical. It indicates within a very narrow margin ideal behavior of stress distribution and development in the members of a welded truss.

Summary of Load Tests

In each case typical column failure of the upper chord between panel points occurred. Three cases failed at the rigid end of the truss and two failed at the free or movable end. At no time throughout these tests was there any indication of joint distress. Approaching failure, by passing the maximum strength of the upper chord was evidenced by Luders lines appearing in the cement coating. In the rivetted and tubular trusses these distress signals appeared before the 9000-lb. panel load was reached.

The loads and factors of safety developed in each case, the weight of each truss and the recorded deflections up to 9000 lb. panel load are given in the following table:

TABLE I. SUMMARY OF RESULTS

Mark	Kind of Truss	Comparable Weight of Trusses	Max. Panel Load	Factors of Safety Developed	Average Deflection		
					3,000	6,000	9,000
Case 1.	Preliminary Truss, Welded	1,199 lb.	10,285 lb.	3.42	.28	.62	1.03
Case 2.	Riveted Truss	1,161 lb.	9,000 lb.	3.00	.29	.635	...
Case 3.	Direct Competitive Welded	1,079 lb.	10,318 lb.	3.44	.25	.585	1.095
Case 4.	Symmetrical Truss, Welded	1,079 lb.	10,043 lb.	3.34	.335	.695	1.13
Case 5.	Tubular Truss Welded	916 lb.	8,877 lb.	2.96	.285	.655	...

Results of these tests, which afforded splendid opportunity for observing the habits of welded construction under conditions of extreme stress, point toward a still greater saving in metal in all members below the top chord. Furthermore, the theoretical amount of metal can probably be used in the secondary web members, now generally heavier than necessary to take the stresses, without causing difficulties as far as welded fabrication is concerned. However, for uniformity of the welded joint a minimum thickness of ¼ in. seems to be desirable for this type of structure.

Further investigations along this line are now being made and a sixth case, designed from the same load specifications governing the previous five, will be developed. This case will utilize rolled tee sections in all tension members and in the sub-struts, having areas agreeing closely with the theoretical requirements and joined by the insert plate method.

Cost

Detail costs of all welded trusses were carefully recorded; the results, however, are not available at this date. From the indications of a cursory survey it is expected that the cost of a welded truss will compare favorably with the cost of riveted one of equal strength.

Conclusions

It is quite apparent that the insert plate joint is a step in the right direction toward the solution of the problem of joining structural steel by oxy-acetylene welding.

Fundamentally and practically, this method of joining is sound.

The summary in Table I shows a rigidity in favor of welding of approximately 15 per cent. This may be explained in part on the assumption that the "fixation" of column members is better than where the end connection is riveted. The reader's attention is again called to the fact that the upper chord angles in all welded trusses were placed tightly back to back, which would be expected to lower the lateral strength of these columns as compared to angles spaced slightly apart.

Material savings in weight of steel necessary for a structure of this type can be made, compared to the present methods of fabrication.

Welding by this method does not inject negative factors of strength in a completed truss structure, nor in the base metal adjacent to the welds. This is evidenced by both the load tests and the strain gage work.

The shop work proved to be simple and attended with but few minor difficulties which were easily remedied. Good alignment of members was maintained by following recognized welding practices. In doing work of this nature, it is recommended that adherence be made to a correct procedure control. In brief, it summarizes as follows:

a—Selection of workmen.
b—Purchase of first-class materials.
c—Provision of good shop conditions.
d—Correct Engineering design for welding.
e—Adequate supervision and management.
f—Inspection and proof test.

By observance of this code, progress in the field of welded fabrication of structural steel can be expected. Caution, and by all means engineering control, on this class of work is imperative. Much remains to be done along these lines, from an engineering and proof testing standpoint before the welding of structural steel will enjoy the confidence of the progressive structural engineer and fabricator. The welding engineer, however, finds much encouragement when witnessing results in practice that conform so closely to his theoretical predictions.

A number of interested engineers were present during all or a portion of the testing of trusses 2, 3, 4 and 5. Among these may be mentioned L. J. Briggs and H. L. Whittemore, of the U. S. Bureau of Standards; J. H. Edwards of the American Bridge Co.; Prof. F. P. McKibben of Union College; F. E. Schmitt of *Engineering News-Record;* Comm. H. E. Rossell of the Navy Department; H. J. Thiede and L. L. Davis of the Engineering Corps, U. S. Army; Douglas Cornell, Chief Engineer, City of Buffalo, and G. T. Snyder of National Tube Company. Pittsburgh Testing Laboratory was retained to report the results.

Acknowledgment is gladly made for suggestions made in informal conference with members of the Bureau of Standards, for aid

and encouragement from G. O. Carter, Consulting Engineer of The Linde Air Products Company, and for the facilities freely given by W. S. Roberts at the Buffalo Engineering Laboratory.

Welding with the Atomic Hydrogen Flame*

R. A. WEINMAN†

In the March, 1926, issue of the *General Electric Review*, Dr. Irving Langmuir explained some of his early observations made of atomic hydrogen in his work in connection with the development of the gas-filled lamp. He also described the effect of heating a filament of tungsten in a vacuum and in such inert gases as nitrogen, argon and mercury vapor at low pressures. In such cases the heat is carried away from the filament by radiation in vacuum and radiation, conduction and convection in the inert gases at a uniform rate up to the melting temperature of the tungsten filament (approximately 3387 deg. C. or 6129 deg. Fahr.). In using hydrogen at low pressure in a lamp having a similar filament, he found that the same conditions hold only up to a temperature as low as 1427 deg. C. (2600 deg. Fahr.) after which the heat loss increased to from two to four times the rate of diffusion at the lower temperatures. This condition is attributed to the dissociation of hydrogen molecules into atoms thereby greatly increasing the heat conductivity away from the filament.

A table is given in this article which shows the degree of dissociation of hydrogen into atoms for different pressures and temperatures of the hydrogen.

Later in the same article Dr. Langmuir gives some idea of the heat of reaction involved in the change of hydrogen from the atomic to the molecular state, namely, a stream of molecular hydrogen of 100 cc. per second rate of flow (about 12 cu. ft. per hour) measured at room temperature if converted into atomic hydrogen at 5000 deg. C. would be capable of supplying energy at the rate of 1.6 kw.

Some idea of the temperature of the atomic hydrogen flame can be gathered from the figures given by Dr. Langmuir. Two grams of hydrogen involve 9800 calories in the heat of reaction which is sufficient to heat the hydrogen to approximately 9000 deg. C. if completely dissociated. However, as he shows, complete dissociation is not possible even under this most ideal condition, and he assumes as a practical maximum degree of dissociation the figure 0.62. With these figures before him, Dr. Langmuir saw that atomic hydrogen might be of great value in the welding of metals, and later made experiments with the electric arc in hydrogen which he explains in his article. In addition to the heat of reaction another factor which tends greatly to increase the tempera-

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†Research Laboratory, General Electric Co.

ture of the atomic hydrogen flame above that when the degree of dissociation is 0.62 and the temperature 4000 deg. C., taken from the table mentioned above, is that it is already heated to a high temperature when leaving the electric arc. These figures may help to give more definite ideas as to the manner in which atomic hydrogen can be used for the melting or welding of metal and also indicate the high heat conductivity of atomic hydrogen, which is a very important factor in welding.

Approximately 30 to 40 cu. ft. of hydrogen per hour are used on the average torch at 2 or 3 lb. gage pressure. It is readily seen from these figures that very little force is required in the stream of gas used. This has a particular advantage of keeping a molten

Fig. 1—Atomic hydrogen flame with an arc of 25 amps

pool under the arc with practically no activity except the removal of such impurities as would react with either atomic or molecular hydrogen, during the fusion of the metal, permitting the gases formed to escape.

In the same issue of the *General Electric Review* and in the JOURNAL of the American Welding Society, March, 1926, an adjacent article by Dr. Langmuir and the writer gives some idea of the operation of the atomic hydrogen flame in the mechanism illustrated and explained. With the further development of this process, however, much consideration has been given to the quantity of heat required for a given thickness of metal, also the characteristics of various metals in the fusion state.

The principal measure of heat is the current consumption, but much refinement of heat regulation can be had by the hand control of the torch. The current in each case is stabilized by the application of sufficient voltage through a series reactance, or resistance. Three hand torches have been developed in different sizes with the object of utilizing current ranges from 3 to 300 amps. These

torches have been applied to thicknesses of metal from 0.005 in. to 2 in. thick, the fusion in each case penetrating the entire thickness of metal.

A great variety of welding work has been carried on in the laboratory during the past year with the atomic hydrogen flame. The greater part of the work has been on alloys which bear such foreign names as to make it not advisable to mention them individually. However, as a number of them closely resemble each other, I may mention the metal constituents individually which have been most common and arrange some of the alloys in their respective grouping. These metals are as follows:

Fig. 3

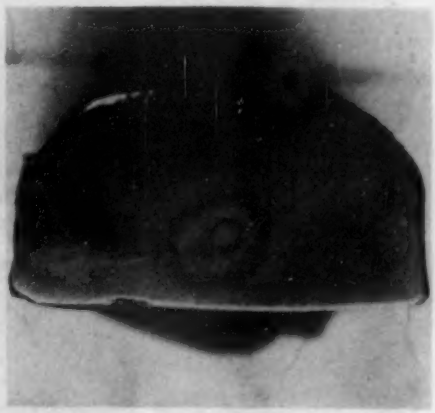


Fig. 2

Fig. 2—Pure aluminum deposit on cold rolled steel

Fig. 3—Microphotograph 100 × showing considerable aluminum dissolved in the steel

Metals

Iron and steel with 0.004 C. to 1.25 C. content:

Copper	Bronze	Nichrome
Aluminum	Monel Metal	Rezistall
Chromium	Stellite	Cast Iron
Nickel	Lead	Silver
Cobalt	Babbitt Metal	Platinum
Tungsten	Alcumite	Silver Solder

Steel Alloys

Chromium steel up to 35 per cent Cr content.
Nickel steel up to 85 per cent Ni content.
Cobalt steel up to 35 per cent Co content.
Molybdenum steel up to 20 per cent Mo content.
Tungsten steel up to 13 per cent W content.
Silicon steel up to 5 per cent Si content.
Aluminum steel up to 13 per cent Al content
Vanadium steel up to 1.5 per cent V content.
Manganese steel up to 12.5 per cent Mn content.

Alloys containing mixture of the following:

Copper, aluminum, nickel and iron.
Iron, aluminum, copper and carbon.
Iron, chromium, nickel, aluminum and carbon.
Iron, chromium, silicon, manganese and carbon.
Iron, aluminum, nickel, silicon and carbon.
Aluminum, zinc and manganese.
Aluminum, silicon and manganese.

There are many other similar alloys or mixtures of metals.

Fig. 4

Fig. 5

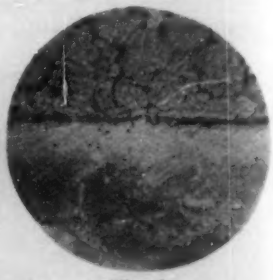


Fig. 6

Fig. 7

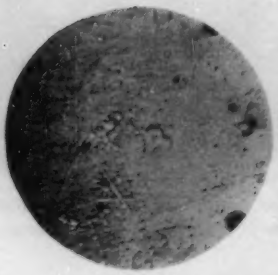


Fig. 8

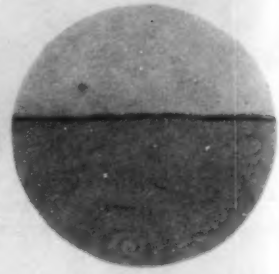


Fig. 9

In addition to the fusion together of like metals, mentioned above, copper and aluminum have been fused onto the surfaces of low-carbon steels, and also on chromium steels containing upward of 13 per cent chromium. Chromium is fused over the surface of low-carbon steels by melting dry chromium powder which is dusted on the metal. Chromizing and calorizing are also done by the atomic hydrogen torch. Calorizing, the introduction of aluminum, is done on boiler tubes without removing them from the boiler.

Vitreous enamel has been applied to soft stamping steel with straight butt welds, and to welds built up with additional metal with the atomic hydrogen flame. Silver has been applied to some metals.

Fig. 1 shows the atomic hydrogen flame with an arc of 25 amp. This flame is used on thicknesses of metal up to ⅛ in. thick, and in many cases it is used to combine two or three thicknesses of 1/16 in. thick, meeting at a common edge, and in some cases one thickness of ⅛ in. to two thicknesses of 1/16 in. are being joined

together at their edges. For 3/16 to ¼-in. metals larger current capacities will give greater speed with the same accuracy.

Fig. 2 shows a pure aluminum deposit on a cold-rolled steel slab ½ in. thick and approximately 4 in. long. Quite a little of the aluminum dissolved into the steel, as shown in Fig. 3 (100 mag.), the boundry of the two metals leaving no marked dividing line. Tests on this sample showed the aluminum was in its original ductile state, and could not be separated from the steel by tearing off.

Fig. 4 shows a 26 per cent chromium steel called Ascoloy No. 1 from which a number of tubes were formed by welding sheet

Fig. 10

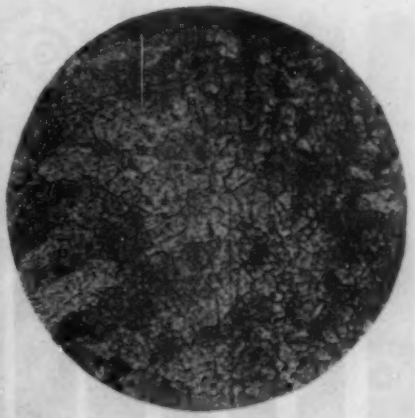


Fig. 11

stock 1/32 to ¼ in. thick. Some of these tubes are illustrated in the March, 1926, *General Electric Review* on this subject. The material shown in the above figure is ⅛ in. thick with 150 mag. This material has been rolled down from ingots of much greater thickness, showing a variety of different sized grains in the structure. A number of seals for glass rectifier tubes are made of this material, having the same expansion coefficient, and in many cases it is welded to low-carbon steel for joining to a metal casing of low-carbon steel.

In Figs. 5 and 6 copper has been welded to the same metal as shown in Fig. 4, namely, Ascoloy No. 1. In Fig. 5 the copper alone has been etched to show how the chromium steel has dissolved into it. Fig. 6, being of a lower magnification, shows the two metals etched, giving some idea of relative grain structure derived in the combination of the two metals widely different in constitution.

Fig. 7 is a section of the same metal (Ascoloy No. 1) with copper spread over the surface, approximately ⅛ in. thick. All but 1/32 in. of the copper was ground off the surface of the Ascoloy, and on examination this showed that quite a little of the Ascoloy was

dissolved in the copper as shown in Fig. 8. Deeper cuts were then made into the junction which showed the boundry lines of the two metals to be very uneven over the entire surface of the Ascoloy base.

Fig. 9 shows a deposit of copper on cold-rolled steel applied in the same manner with the atomic hydrogen flame. The boundary line of these two metals is jagged the same as in the former cases, much of the steel being dissolved into the copper.

Fig. 10 shows copper welded to Invar, a steel containing 35 per cent nickel, the Invar being 20 mils thick. The largest section of

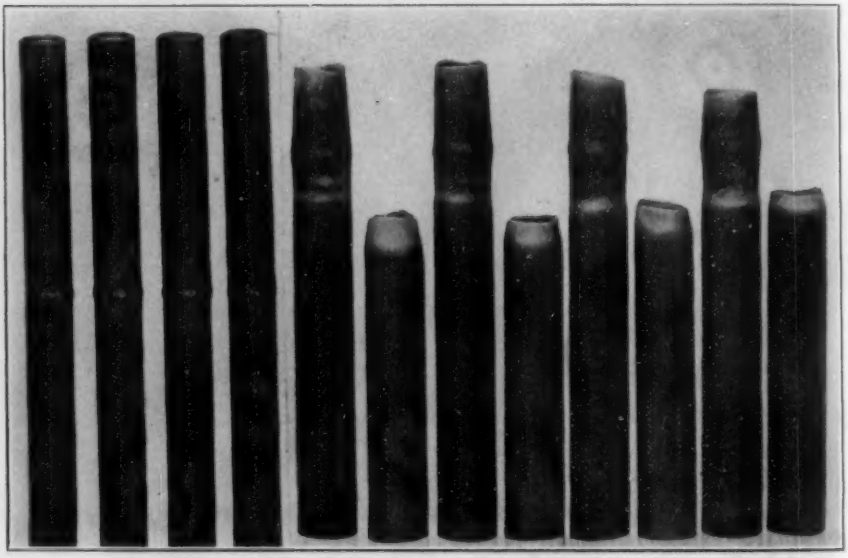


Fig. 12 Fig. 12a

Fig. 12—Tubes welded with atomic hydrogen
Fig. 12a—Tubes after tensile tests were made. Note break outside of weld

the copper is approximately 60 mils thick. The copper flows in this metal very freely under the atomic hydrogen flame.

Fig. 11 shows a weld made on alcumite, a metal containing for a base copper with aluminum, iron, and nickel, the larger grains representing the parent metal, and the smaller the weld between two adjacent pieces of the metal. This, of course, is the reverse of what would occur in the majority of metals welded. If you notice, however, the only mark of boundary between the weld and parent metals is the refinement of grain in the welded section.

Figs. 12 and 12-A show tubes 1 in. in diameter with 1/16 in. walls approximately 18 in. long, made of 0.35 carbon steel with 0.50 manganese content, with weld in center. These welds were made without any backing under the weld, the bead of additional metal being less than 1/16 in. above the outside diameter of the tubes.

Fig. 12-A shows the tubes after tensile tests were made on them (no heat treatment was given). The tubes and the strips of cold-rolled steel shown in Fig. 13 gave a Rockwell hardness test as shown in Fig. 14. The characteristic curve, illustrated in Fig. 14, has been found to serve all low-carbon steel welds where no heat treatment has been applied. The table below gives a test recently made on boiler-plate iron with and without welds which

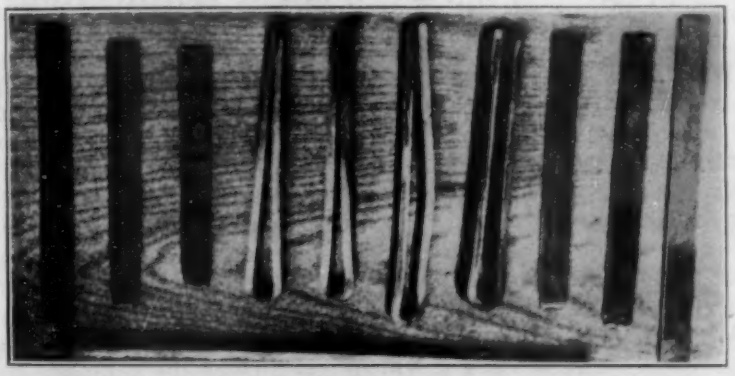
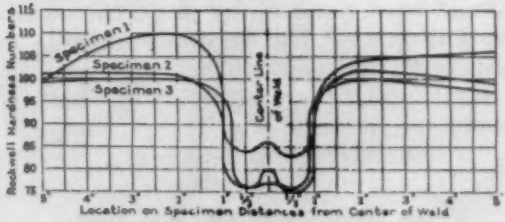


Fig. 13



Rockwell Hardness Tests on Hydrogen Arc Welds

Fig. 14

have been reduced by forging in thicknesses from 1 to ¾ in. thick and annealed.

Sample No.	With Welds		Without Welds	
	Yield	Ultimate Tensile Strength	Yield	Ultimate Tensile Strength
1	29,600	51,700	30,000	52,700
2	27,300	51,600	31,000	53,500
3	28,000	53,400	28,200	52,200
4	27,400	52,400	31,900	53,100
5	27,600	53,100	27,000	50,500
6	25,800	53,000	29,000	52,200
7	29,900	55,300	25,500	51,700
8	31,000	53,000		

The results attained by our laboratory with this process indicate quite clearly that welds can be made by it which cannot be made by any other known means. However, the apparatus is

hardly out of the laboratory stage, and requires further development to suit general commercial conditions. It will be several months before commercial apparatus will be ready for sale.

Structural Steel Joints Fundamentally Designed for Arc Welded Connections*

By A. M. Candy†

Within recent years there has probably been no development of more vital interest to the steel workers and building industry at large, than the series of tests recently conducted at Carnegie Institute of Technology in Pittsburgh, Pa., by our company. These tests proved so conclusively that properly designed and fabricated arc welded connection have so many merits that a contract was awarded to the American Bridge Company to construct a 5-story, 70 x 220-ft. mill-type building 80 ft. high at the Sharon Works of the Western Electric & Mfg. Company.

We believe that the data on these tests will be desired by the engineering and welding world in advance of the complete data on this building. The complete series of tests included a total of twenty-two specimens typifying various structural joints and members which would most conclusively prove the merits of the process to engineers who have not had an opportunity to make a study of this work. Space limitations will not permit an exhaustive study of all the specimens and therefore we will only give details of the most interesting specimens.

The design of column connections offers a very interesting study in that continuity may be obtained with arc welding at much less expense than where riveted designs are used. Furthermore, the welded connections are stronger than the conventional riveted connections.

To substantiate these ideas a series of three test specimens were built as illustrated by Fig. 1. Each specimen comprises an H column 8 in. deep, 2 ft. high, weighing 32 lb. per foot and two cantilever Bethlehem I beams 9 in. deep, 3 ft. long, weighing 20.5 lb. per foot. The detail connections for the specimen are as follows:

Specimen No. 2 was constructed by welding two seat angles 4 x 3 x ⅜ x 6½ in. long, across the faces of the column with the 4-in. legs outstanding. Only the ends of the 3-in. legs were welded to the column with a 5/16-in. bead. This welding was done in a downward direction by turning the column to typify shop fabrication. Four continuity plates each 3 x ⅝ x 6⅝ in. long were then located against the web of the column between flanges so as to be directly in line with the flanges of the cantilever beams. The column was turned to permit all downward welding the same as for the seat

*To be presented at Fall Meeting, A. W. S., Buffalo, November, 1926.
†Welding engineer, Westinghouse Electric & Manufacturing Company.

angles. These continuity plates were heavily welded with a 3/8-in. fillet entirely around their ends against the column flanges. The column was then placed on end and the I-beams were landed on the seat angles with approximately a 3/16-in. opening between the beam ends and the column faces. The entire ends of the beams were then welded to the column faces. Also the edges of the beams were welded 4 in. along the line of the outstanding legs of the seat angles. Two top reinforcing plates each 4 x ½ x 4½ in. were then located on top of the beams with the 4-in. lengths adja-

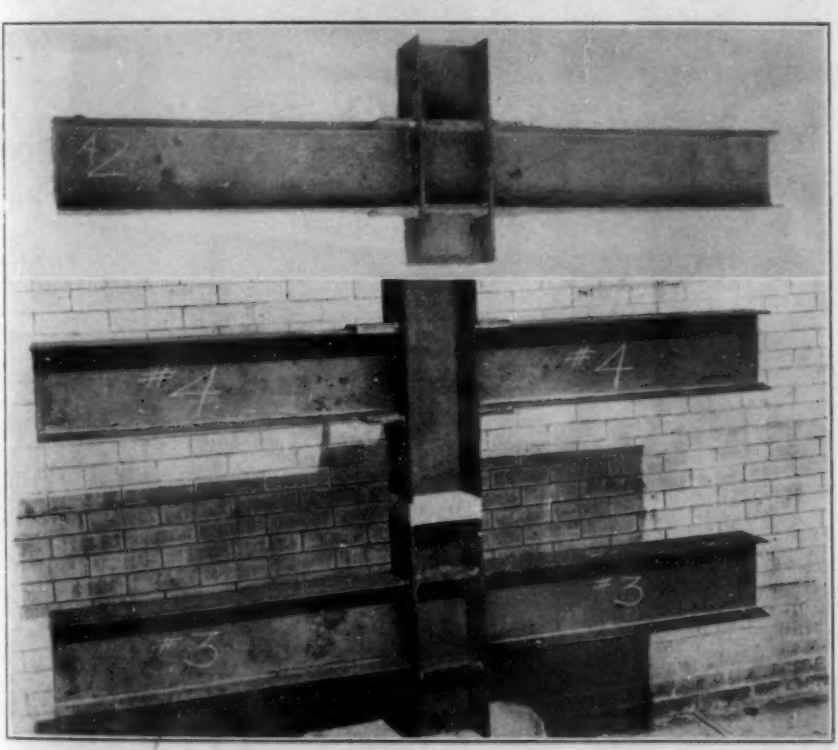


Fig. 1—Specimens before test

cent to the column faces. These ends were welded to the column faces and the 4½-in. lengths were welded to the top flanges of the beams.

Specimen No. 3 differed from No. 2 in that no seat angles and no reinforcing plates were used.

Specimen No. 4 differed from No. 2 in the very vital item of omitting the "continuity" plates from the column flanges.

Each of these specimens was turned upside down and mounted on rocker blocks 5 in. wide located with their centers 3 in. from the beam ends, thereby providing a span of 6 ft. 2½ in., the load being applied on the upstanding end of the column.

The results of the tests are shown in Fig. 2. Curve in Fig. 3

shows the stress diagrams of the three specimens to permit of direct comparison. The following table gives the pertinent data:

Specimen No.	Pounds Elastic Limit	Pounds Ultimate Load	Bending Moment at Column Face in Inch Pounds	Remarks on Ultimate Load
2	57,000	70,000	116,500	No. 2—40% higher than No. 4
3	50,000	60,000	100,000	No. 3—20% higher than No. 4
4	28,000	50,000	83,000	No. 2—16% higher than No. 3

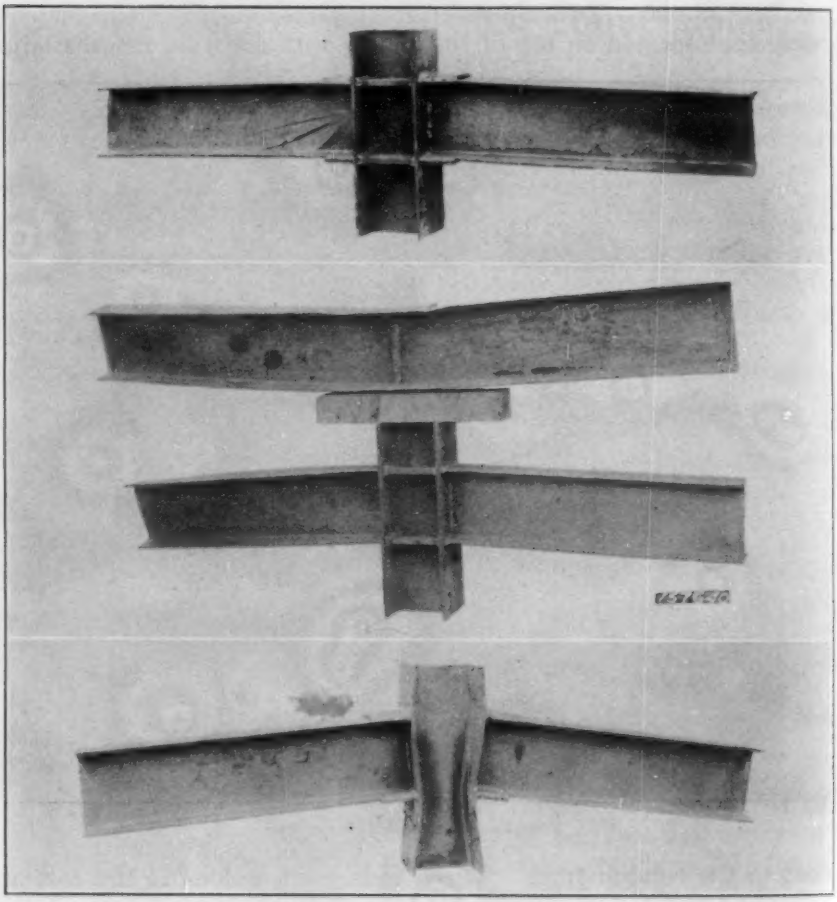


Fig. 2—Specimens after test
Specimen No. 2 upper figure, No. 3 center figure, No. 4 lower figure

It is interesting to observe that none of the specimens had a single failure in the welds. Specimens No. 2 and No. 3 failed by web crippling of the cantilever beams and No. 4 by web buckling of the column. The fact that No. 2 shows 16 per cent greater ultimate capacity than No. 3 is attributed to the stiffening effect both in the vertical and horizontal planes produced by the top reinforcing plates and the outstanding legs of the seat angles. The very marked difference between No. 2 and No. 4 is, of course, due to the "con-

tinuity" plates in the column of No. 2 which produce an effect identical with that of having the two cantilever beams carried continuously through the column. This construction is to be carried out completely through the Westinghouse Sharon building.

To show the advantages gained by simply substituting arc welding for riveting in tension members, two specimens were prepared

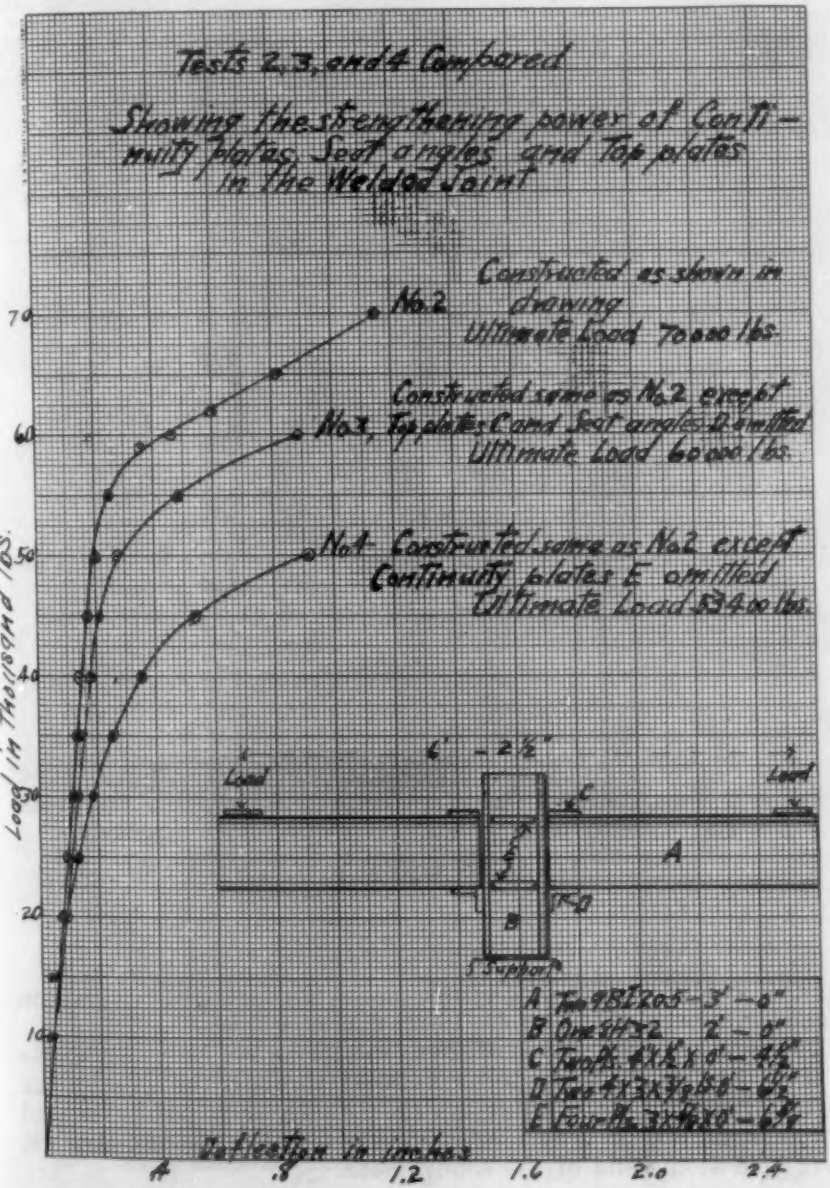


Fig. 3

as shown by No. 17 and No. 18 in Fig. 4. Specimen No. 17 comprises two angles 2½ x 2 x 3/16 x 48 in. long with their 2½-in. legs located against two shank plates ¾ x 5 x 12 in. with the angles overlapping the plate ends 4 in. The heel and toe of each angle was welded along the 4-in. length and across the ends of each angle to the shank plates. Specimen No. 18 differed slightly in that the angles were 4 ft. 2½ in. long, overlapped the shank plates by 6½

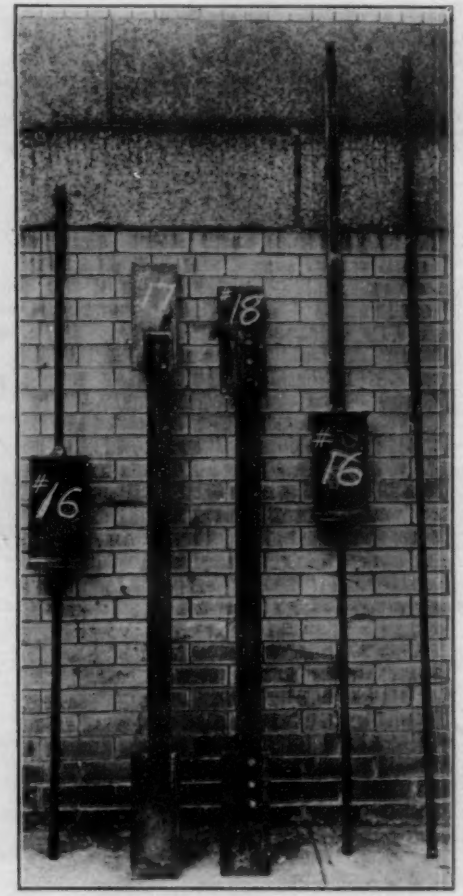


Fig. 4

in. and were riveted to the shank plates with six rivets ⅝ in. in diameter, power driven in 11/16-in. diameter holes.

The comparative failures of these specimens are shown by curve in Fig. 5. The welded specimen failed through the 2½ in. leg first, followed by tearing through the 2-in. leg adjacent to the end of the shank plates. The riveted specimen failed through the first rivet hole at the end of the shank plate.

The following table gives the pertinent data:

Specimen No.	Pounds Elastic Limit	Pounds Ultimate Load	Ultimate Load in Pounds per Sq. In. of Sectional Area of the Two Angles
17	70,000	94,000	58,000
18	60,000	72,000	44,500

In addition to the fact that the welded specimen was more than

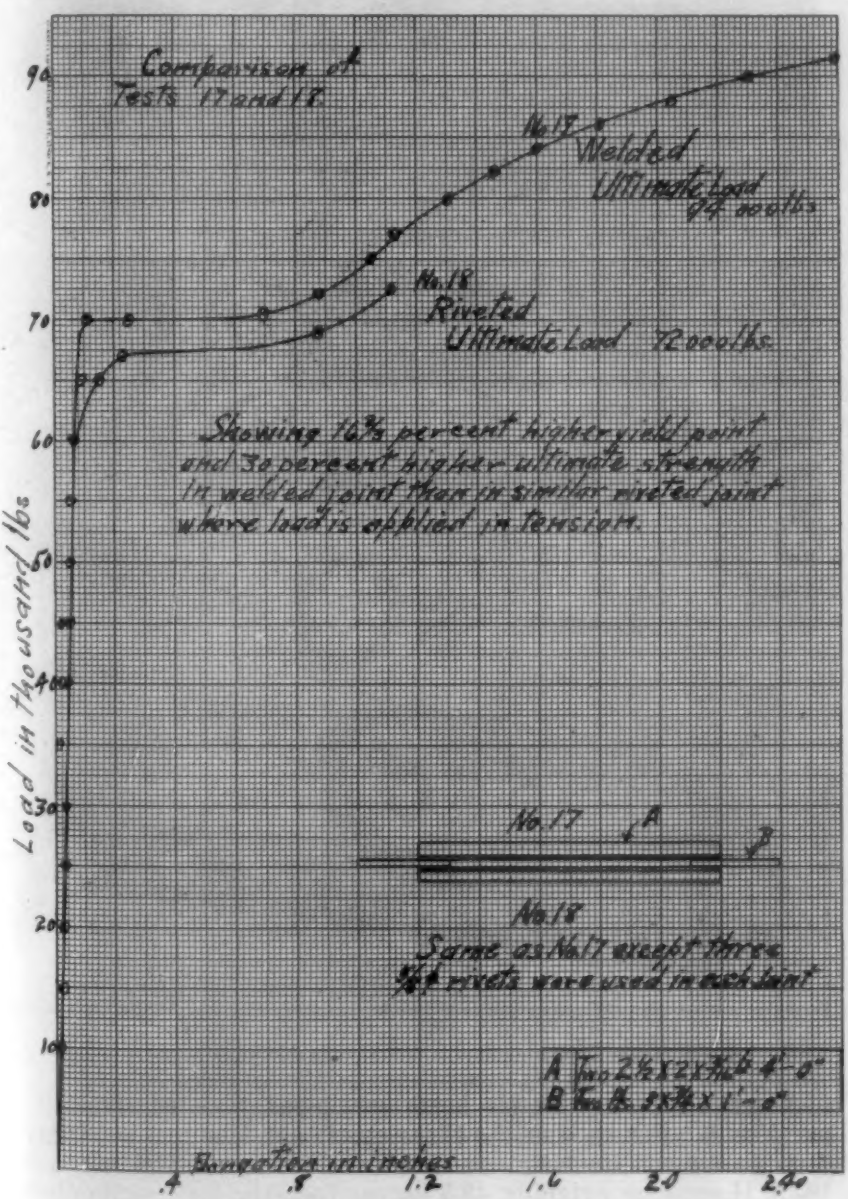


Fig. 5

30 per cent stronger than the riveted specimen, it is interesting to note in passing that the elongation of the welded specimen was 168 per cent greater than the riveted specimen, the values being 1.12 in. for the riveted specimen and 3 in. for the welded specimen measured over a length of 40 in.

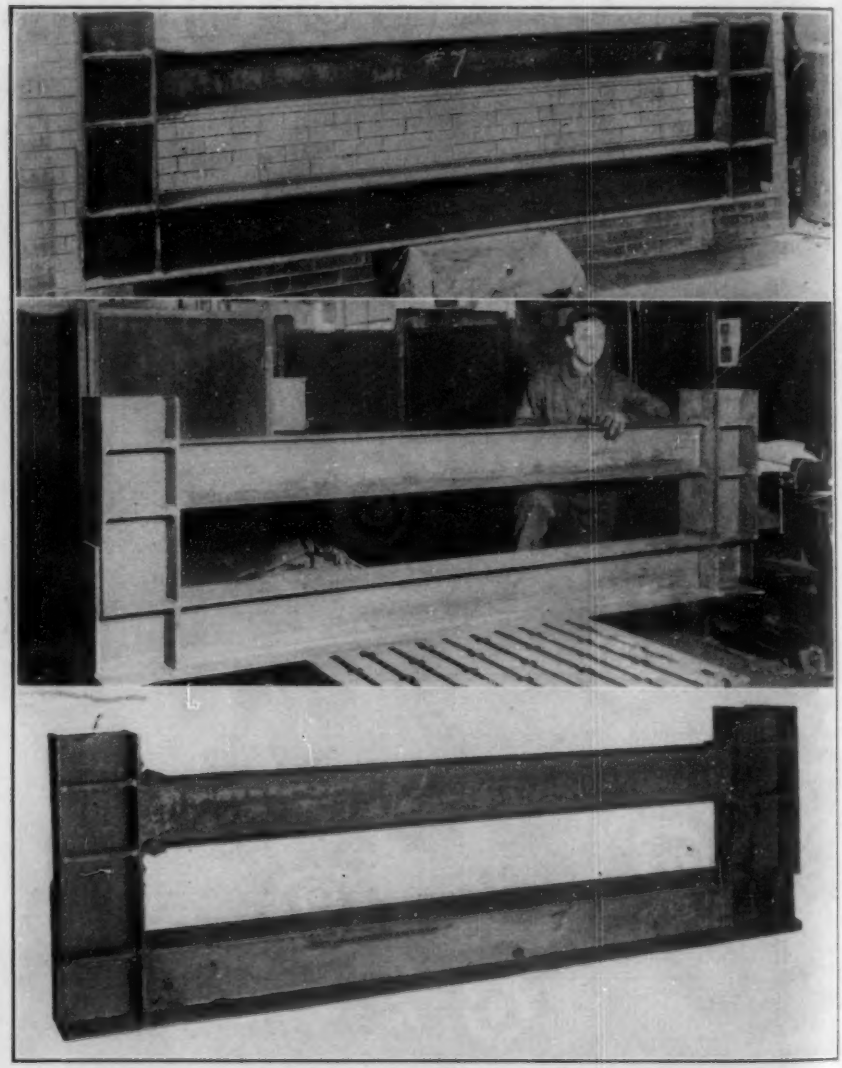


Fig. 6
Specimen No. 7 upper figure, No. 8 center figure, No. 9 lower figure

A series of three simple beam specimens were constructed as per Fig. 6. For each of the three specimens identical superstructures to support the beams were constructed by arc welding, using 10-in. H sections weighing 49.5 lb. per foot, the base section being

9 ft. 7¾ in. long and the column sections being 2 ft. 3 in. high. The "continuity" plates were ⅝ x 4 x 8¼ in. long. The back stress plates tying the column faces to the base web were ½ x 6 x 16 in. long. The beam member of each specimen was a 9-in. I weighing 21.8 pounds per foot, 7 ft. 11⅜ in. long.

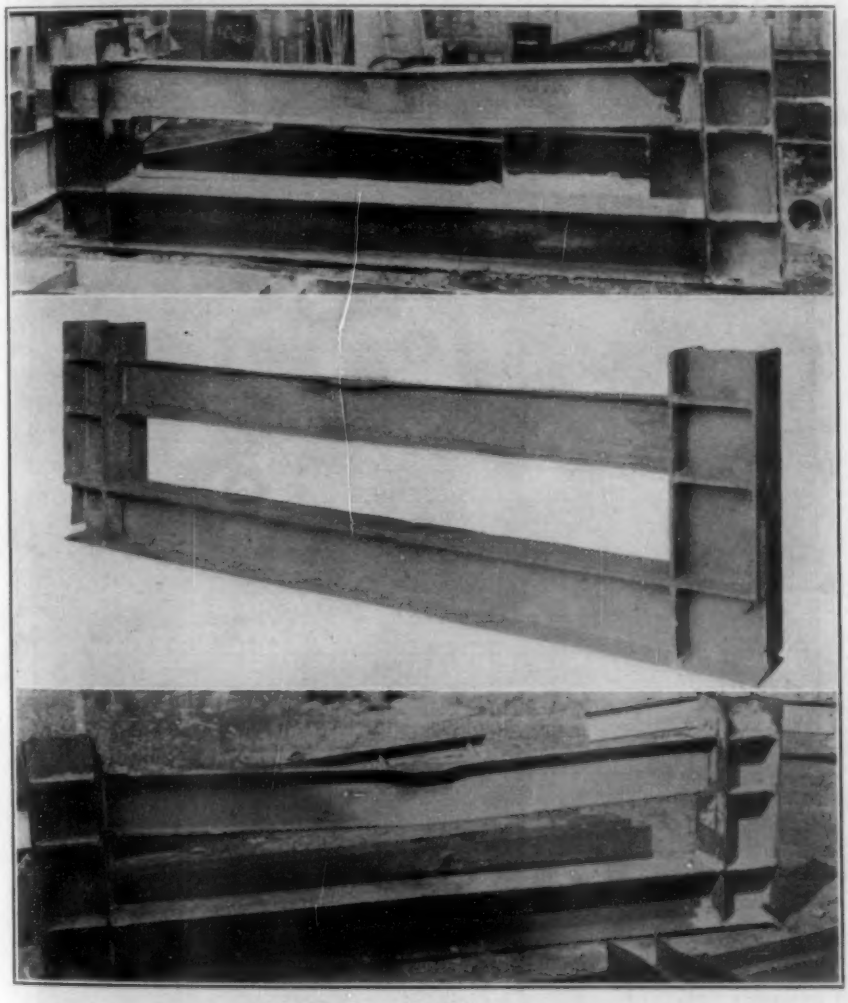


Fig. 7
Specimen No. 7 upper figure, No. 8 center figure, No. 9 lower figure

In the case of specimen No. 7 two seat angles 3 x 4 x ⅜ x 5 in. long were welded along the ends of the 3-in. leg to the columns. The structure was then turned in the upright position and the beam was landed in position on these seat angles. The beam ends were then welded to the column faces and landing angle; also reinforcing top plates 4 x 7/16 x 5 in. long were added and welded exactly as described for specimen No. 2.

Specimen No. 8, Fig. 6, differs only from No. 7 by the omission of the seat angles and top reinforcing plates for the beam to column connections.

Specimen No. 9, Fig. 6, is materially different in that the beam to column connections follow standard riveted practice. Two top and bottom angles ½ in. thick and a total of twenty rivets ¾ in.

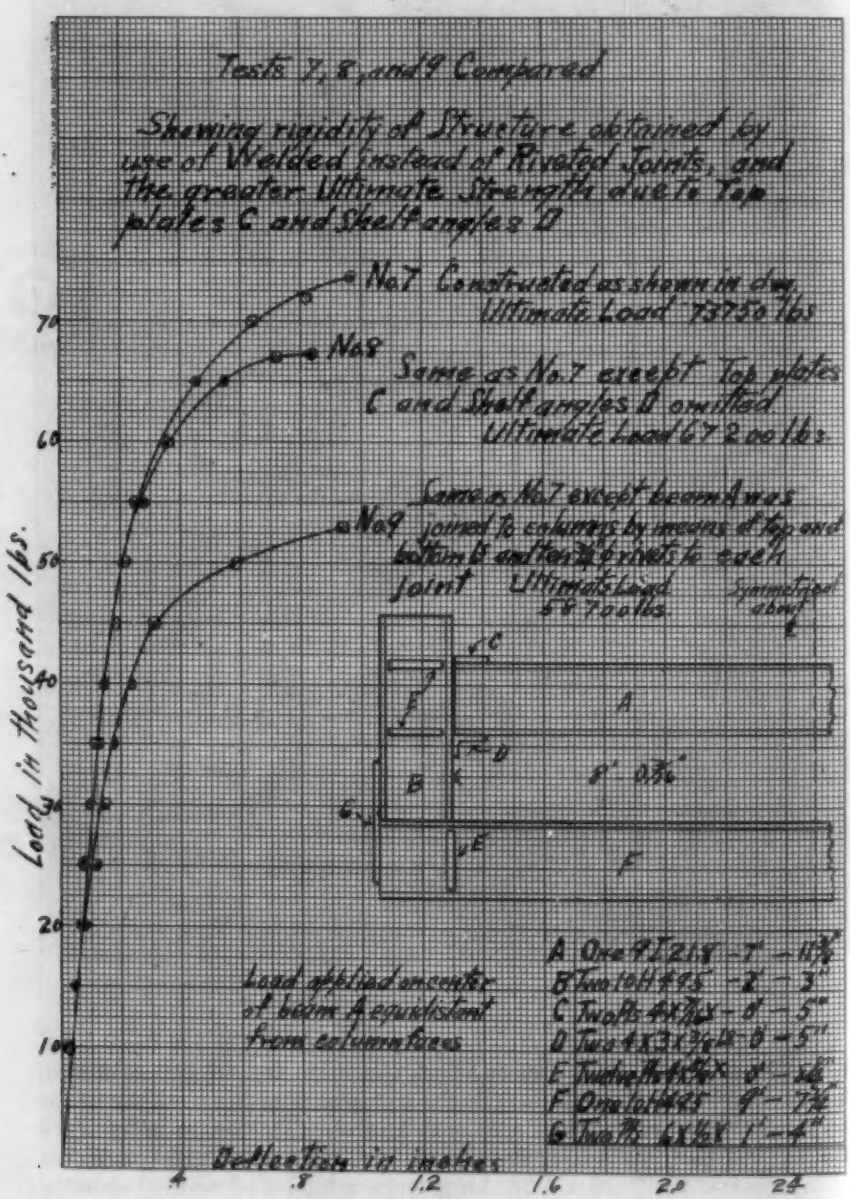

Tests 7, 8, and 9 Compared
Showing rigidity of Structure obtained by use of Welded instead of Riveted Joints, and the greater Ultimate Strength due to Top plates C and Shelf angles D
No 7 Constructed as shown in dwg. Ultimate Load 73750 lbs
No 8
Same as No 7 except Top plates C and Shelf angles D omitted Ultimate Load 67200 lbs
No 9
Same as No 7 except beam A was joined to columns by means of Top and bottom B and ten ¾ rivets to each joint Ultimate Load 58700 lbs
Symmetrical about ℄
Load in Thousand lbs.
Deflection in inches
Load applied at centre of beam A equidistant from columns ℄
A One 9" I 21.8 - 7' - 11⅜"
B Two (of) ℄ 6 x 6 x ⅝ - 2' - 3"
C Two Pl. 4" x 7/16" x - 0' - 5"
D Two ∠ 4 x 3 x 7/16 x - 0' - 5"
E Two (of) ℄ 6 x 6 x ⅝ x 8' - 4"
F One (of) ℄ 6 x 6 x ⅝ 9' - 7½"
G Two Pl. 6" x 6" x ½" 1' - 4"

Fig. 8

in diameter, power driven in 13/16-in. diameter holes, were used.

Each of the specimens was centrally loaded on a block 1½ x 5 x 8 in. long placed with the 8-in. dimension across the top flange of the beam. In each of the three specimens failure took place by web crippling and flange buckling, at the center of the beam as per Fig. 7. It is interesting to note, however, that in the case of the riveted specimen No. 9, although the major failure was web crippling at the center of the beam, a preliminary failure by bending of the top angles produced a V-shaped opening between the

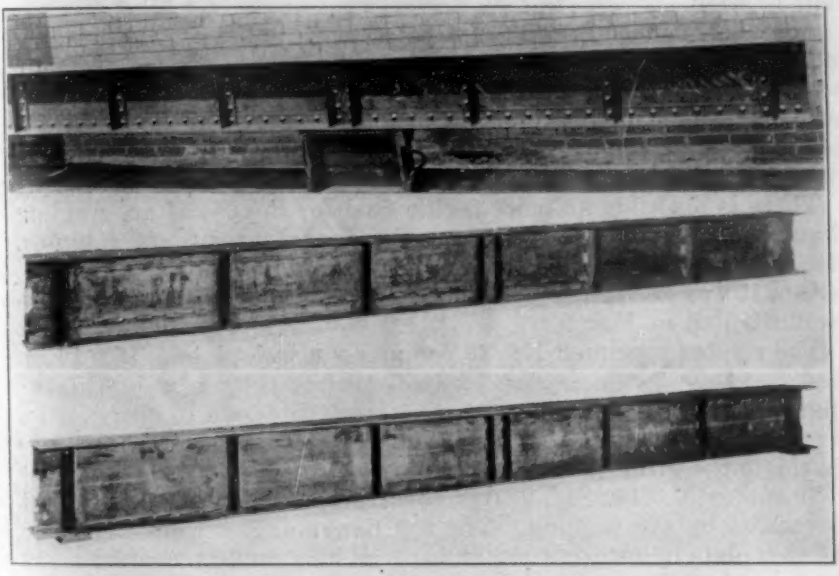


Fig. 9
Specimen No. 20 upper figure, No. 19 center figure, No. 21 lower figure

beam end and column faces as illustrated at left end of beam in Fig. 7. This preliminary failure of the top angles was responsible for the early ultimate failure of the specimen as shown by curve in Fig. 8 and the following table:

Specimen No.	Pounds Elastic Limit	Pounds Ultimate Load	Remarks on Ultimate Load
7	50,000	73,500	No. 7—25% higher than No. 9
8	50,000	67,200	No. 8—14% higher than No. 9
9	42,000	58,700	No. 7— 9% higher than No. 8

As in the case of specimens No. 2 and No. 3 we attribute the superiority of No. 7 over No. 8 to the stiffening effect, in both vertical and horizontal planes, produced by the top reinforcing plates and the outstanding legs of the seat angles.

In the case of specimen No. 7 the sum of the positive and negative bending moments was 1,760,000 inch pounds. As the welds showed no distress and as the columns did not perceptibly deflect, the negative moment at either end must have been nearly as great

as the positive moment at mid-span. For purposes of comparison with tests 8 and 9; assume this test a case of perfect fixed ends, positive and negative moments being each 880,000 inch pounds. This corresponds to maximum fiber stress of 46,500 lb. per square inch.

For specimen No. 8 the sum of the positive and negative bending moments was 1,618,000 inch pounds. Assuming same ultimate positive bending moment as in test No. 7, the negative moment at column face would be 738,000 inch pounds, indicating 84 per cent fixation.

For specimen No. 9 the sum of positive and negative bending moments was 1,410,000 inch pounds. Assuming same ultimate positive bending moment as in test No. 7, negative moment would be 530,000 inch pounds, indicating 60 per cent fixation. Such a degree of fixation could not have been obtained with an ordinary type angle 5/16 or ⅜ in. thick.

There is probably no more fertile field for the use of arc welding than that afforded by built-up members, such as girders, columns, etc., which exceed the sizes of existing rolled shapes. For this reason it was decided to build up a series of four specimen girders as illustrated in Fig. 9.

The riveted specimen No. 20 comprises a web plate 5/16 x 14 in. x 15 ft.; four flange angles 3 x 4 x 5/16 in.; sixteen web stiffener angles 2½ x 3 x ¼ in. and filler plates. A total of 116 rivets ¾ in. diameter power driven in 13/16 in. diameter holes were used to fabricate the girder.

Specimen No. 19, Fig. 9, was constructed of the same parts but assembled by arc welding. The top flange angles were welded to the web plate by intermittent welds 1 in. long on 3-in. centers along the toe of both the top angles. *The backs of the angles were welded together and to the edge of the flange plate intermittently using 2-in. long welds on 3-in. centers.* At each end the angles were welded solid to the web plate at both the heel and toe for a distance of 3 in. The bottom flange angles were welded to the web plate solid for a distance of 6 in. at each end of the toe, the remainder of the weld along the toe of the angle being 2-in. on 5-in. centers. *The heels of these angles were welded solid and also to the edge of the web plate for a distance of 6 in. The remaining portion of this same joint was intermittently welded 2-in. on 5-in. centers.* The filler plates were welded to the web plate by means of 2-in. long welds at the neutral axis and ½-in. welds at the ends of the filler plates along the web plate. The stiffener angles were completely welded around the entire periphery, making contact with the flange angles, and also 2-in. welds at the heel and toe of these angles exactly in line with the 2-in. welds made at the edge of the filler plates to the web plate. The completed specimen weighed 785 lb. The amount of welding wire required to complete the specimen was 27 lb. 8 oz. The total time to complete the specimen was 14 hours and 10 minutes.

Specimen No. 21, Fig. 9, was designed strictly to take all advantage of the possibilities of joining structural steel members by the use of arc welding to produce a girder of equal strength using less weight of steel. In this respect it is entirely different from No. 19, which is simply a riveted design welded.

The specimen comprises a web plate 14 x 5/16 in. x 15 ft. long;

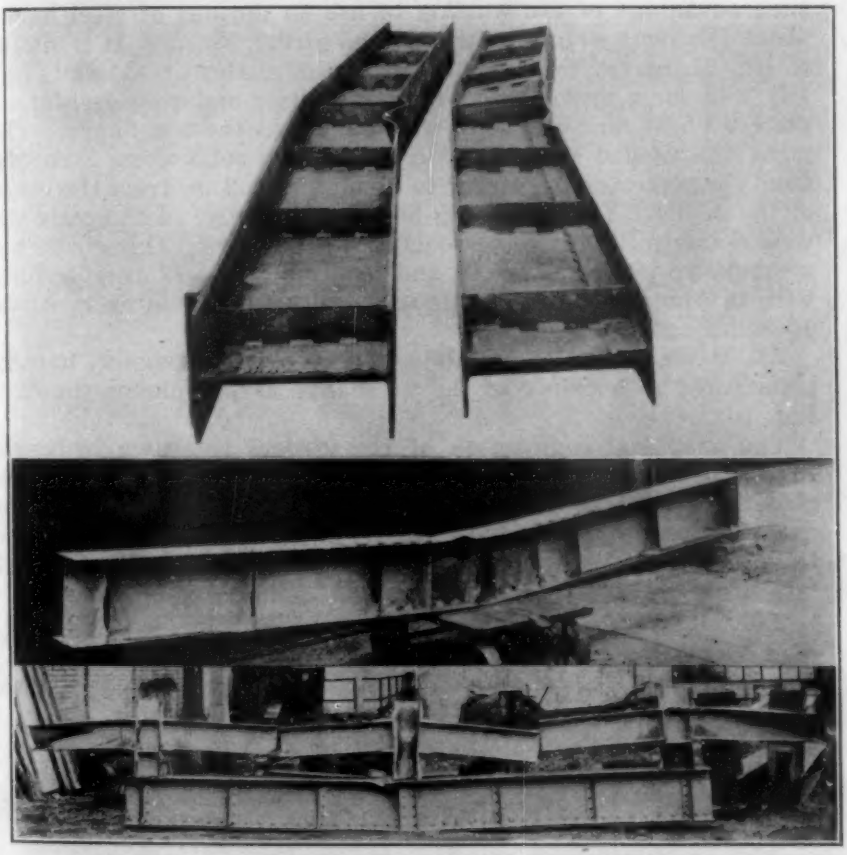


Fig. 10
Specimen No. 21 upper figure, center figure No. 21A, lower figure No. 20

two flange plates 10 x 3/8 in. x 15 ft. long; and 16 web stiffener plates 3 x 1/4 in. x 1 ft. 1 3/4 in. long. The top flange was welded to the web plate continuously along each side of the web plate. The bottom flange was welded to the web plate solid for a distance of 6 in. from each end and then intermittent welds 2 in. long on 4-in. centers the rest of the distance on each side of the web plate. The web stiffeners were welded solid to the flanges around the entire periphery at each end of each web stiffener. Each web stiffener was also welded 2 in. on each side at the neutral axis and at intermediate points 1-in. long at each side of each stiffener, half way

between each stiffener and the flanges of the girder. This specimen had a total finished weight of 656 lb., which is 18 per cent less than that of the riveted girder No. 20, which weighed 798 lb.; and 16 per cent less than (the riveted design welded) specimen No. 19, which weighed 785 lb.

Specimen No. 21-A, Fig. 10, was also designed to take all possible advantage of arc welding to use an amount of steel having about the same weight as the riveted girder No. 20. It is similar to No. 21, except that the web stiffening plates are 4½ x ¼ in. x 1 ft. 2 in. long, there being a total of 20 used and a top reinforcing plate 9 x 5/16 in. x 6 ft. long was welded to the top flange. This plate was welded solid across each end and solid along each edge from the center of the girder to a point 1 ft. 2 in. from the center of the girder. The remaining length of the edge of the plate was welded intermittently 2-in. welds on 4-in. centers. This girder had a completed weight of 795 lb. and required 30 lb., 12 oz. of welding wire to complete the welding work. The total welding time was 16 hours and 50 minutes.

All of these girders failed in a very similar manner, namely, principally by buckling of the top flange as per photos shown in Fig. 10.

The graphical comparison of the girders is shown by curve, Fig. 11, on which appears the tests for the two duplicate riveted girders Nos. 20 and 20-A. In the following table the pertinent data is given in which the data given for the specimen 20-B is the average of the data for the two specimens, Nos. 20 and 20-A.

Specimen No.	Pounds Weight	Pounds Elastic Limit	Pounds Ultimate Load	Maximum Bending Moment, Ft. Pounds	Maximum Fiber Stress, Lb. per Sq. In.
19	785	65,000	77,200	270,000	53,800
20-B	798	57,500	71,450	250,000	49,200
21	656	65,000	78,000	273,000	52,700
21-A	795	60,000	110,350	386,000	

COMPARATIVE DATA

Weight	Ultimate Load
No. 21-A is ½% below No. 20-B	No. 21-A is 59% above No. 20-B
No. 21 is 18% below No. 20-B	No. 21 is 9% above No. 20-B
No. 19 is 1½% below No. 20-B	No. 19 is 8% above No. 20-B
No. 21 is 16½% below No. 19	No. 21 is 1% above No. 19

A few deductions of interest may be drawn from these girders, for example, since Nos. 19 and 20 are made up from duplicate parts one should be as strong as the other. We find, however, that although No. 19 is slightly lighter, it developed 8 per cent greater strength. This is attributed to the fact that welded connections are much more rigid than riveted connections, but the feature of even greater importance is the fact that the heels of the flange angles were welded together and to the edges of the web plate, which makes the two sets of flange angles practically the equivalent of a solid plate, therefore, materially stiffening these members as compared with the riveted construction.

During the tests of these girders none of the welds showed any signs of distress even at the points of maximum stress. Fig. 12

shows a close-up of No. 21 taken of the weld joining the web and top flange at the point of maximum buckling, and also of specimen No. 19 and specimen No. 21-A.

All of the above girders were tested by central loading on a bearing plate 1½ x 5 x 8 in. long, placed lengthwise across the top flange of the beam.

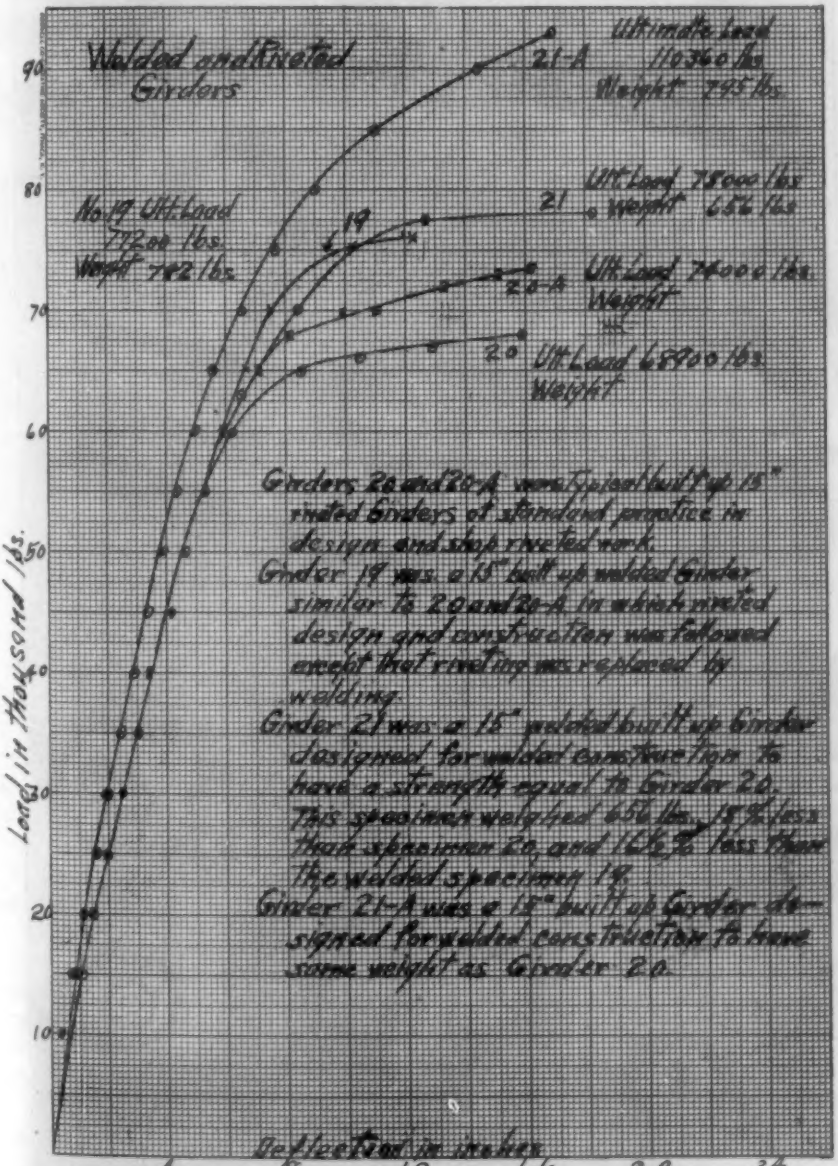

Welded and Riveted Girders
21-A
Ultimate Load 110360 lbs
Weight 795 lbs.
No. 19 Ult. Load 77200 lbs
Weight 762 lbs.
19
21
Ult. Load 78000 lbs
Weight 654 lbs.
20-A
Ult. Load 74000 lbs.
Weight
20
Ult. Load 68800 lbs.
Weight
Girders 20 and 20-A were Carnegie built up 15" riveted Girders of standard practice in design and shop riveted work.
Girder 19 was a 15" built up welded Girder similar to 20 and 20-A in which riveted design and construction was followed except that riveting was replaced by welding.
Girder 21 was a 15" welded built up Girder designed for welded construction to have a strength equal to Girder 20. This specimen weighed 654 lbs. 17% less than specimen 20, and 126 lbs less than the welded specimen 19.
Girder 21-A was a 15" built up Girder designed for welded construction to have same weight as Girder 20.
Load in Thousand lbs.
Deflection in inches
90
80
70
60
50
40
30
20
10
4
8
1.2
1.6
2.0
24

Fig. 11

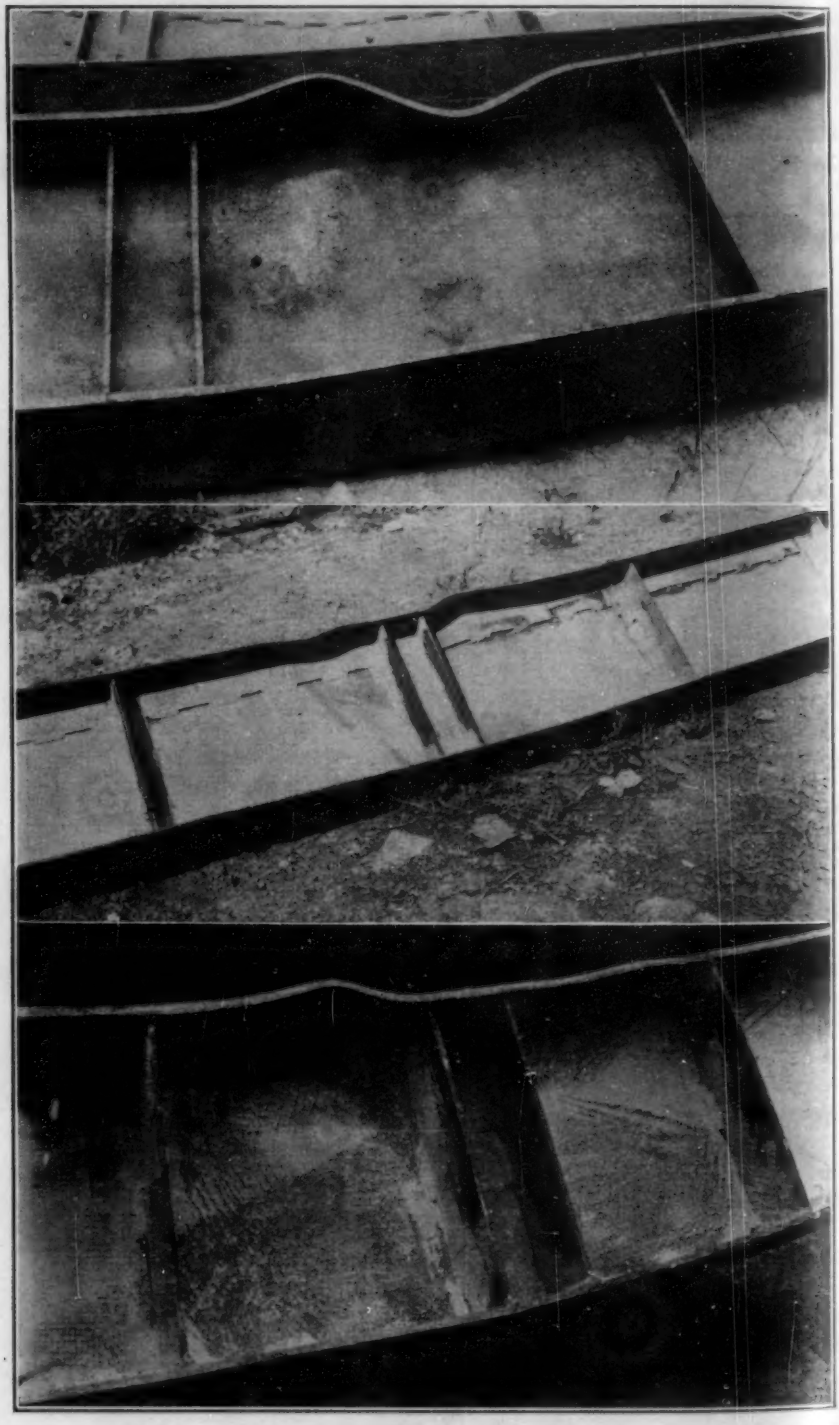


Fig. 12
Specimen No. 21 upper figure, No. 19 center, lower No. 21A

Summary

By perusal of the data which is given in this article it is manifest that the tests fully demonstrate the following facts:

(1) The tests demonstrate that welded joints can be constructed in such manner as to develop fully the ultimate strength of the structural members connected.

(2) Beams and girders can be connected to columns so as to produce absolute fixation.

(3) Lines of beams or girders can be connected so as to provide complete continuity across the supports, whether the supports be girders or columns.

(4) That a steel I beam of given section and length will sustain a far greater load if fixed at its ends by a suitably designed welded joint than if supported by standard riveted connections consisting of top and bottom angles. A 9-in. standard I beam framed between rigid upright columns 8 ft. apart by means of specially designed welded connections sustained a load 25 per cent greater than a beam of the same size and length framed between columns by means of riveted top and bottom angles of ½-in. thickness.

(5) A plate girder assembled by welding and consisting of nothing but sheared plates, has a far greater bending strength than a riveted plate-and-angle girder of the same weight, due to the better distribution of the steel in the cross section. A 15-in. plate girder assembled by welding and simply supported on a 14-ft. span developed more than 50 per cent greater strength than a riveted plate-and-angle girder of the same depth and the same weight.

(6) A double angle tension member such as is used in trusses was connected at the ends by welding, and when tested to tension failure broke through the angles at a load 30 per cent greater than the load at which a hanger consisting of the same size angles with riveted end connections failed.

The prevailing impression among the witnesses was that these tests demonstrated the superiority of welded connections to riveted connections in every case where direct comparisons were made, and brought out two general facts:

(1) That complete continuity of lines of beams can be obtained in welded construction, whereas it is well known that this cannot be done in riveted construction.

(2) That in a welded building it will be possible to make every joint develop full strength of the main members, whereas in a riveted building many joints are weaker than the members due to the weakening effects of the rivet holes and the weakness of steel angles which have to be used for transmitting tension between two members at right angles to each other.

It was proved that a welded plate girder was 50 per cent stronger than the riveted girder of relative depth, length and weight.

An Olsen testing machine, capable of applying 400,000 lb., was used.

The tests proved the entire practicability of welding without any misgivings as to safety.

The joints that were demonstrated here are being used in the five-story steel building, 70 x 220 ft., 80 ft. high, now being fabricated and erected by the American Bridge Company for the Sharon Works of the Westinghouse Electric & Mfg. Company. The typical beam and girder connections are fully continuous connections, thereby permitting large percentage (about 12 per cent) of saving in the weight of the beams and girders to carry a given load. The same type of connection which develops continuity also effectively stiffens the building against wind. The equivalent cannot be obtained by any known riveted joint.

Creditory

The design of the test specimens described above, and the design for the welded steel building for the Westinghouse Electric & Mfg. Company at Sharon, Pa., were produced by Gilbert D. Fish, consulting structural steel engineer, cooperating with the arc welding engineers of the Westinghouse Company.

All material for these test specimens was furnished gratis by the American Bridge Company, and was specially prepared under the direction of Marshall Williams, assistant to president of that company. Complete data upon the physical properties of all of this steel, including tensile tests and chemical analyses were also supplied, and great care was taken in selecting the steel material so that in so far as possible, it would be from the same heat so as to secure uniformity in comparing the various specimens.

All of the testing work was carried on at the Carnegie Institute of Technology by J. M. Daniels, instructor in charge of the Materials Testing Laboratory, and his assistant, Arthur Haeppel. The actual welding of the specimens and all records of tests were carried out under the direction of A. M. Candy, welding engineer, and C. T. Eakin of the Material and Process Engineering Department of the Westinghouse Company.

The Westinghouse Electric & Mfg. Company hereby desires to record acknowledgment of the service rendered in this work by all of the above mentioned parties and assistants working under them.

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Torch Solves Difficult Piping Problem. Martin Vanderveer, Power (Oct. 5, 1926), Vol. 64, pp. 510-11.

"Up-Hill" Pipe Welding, The Welding Engineer (Sept., 1926), Vol. 11, p. 23.

Welded Pipe Line Progress on Oakland Water Supply Line. Engineering World (September, 1926), Vol. 29, p. 159. Illustrates the arc-welded pipe used in the 90-mile line for Oakland, Calif.

Welded Steel Stacks Avoid Corrosion at Joints. Power Pl. Engineering (Aug. 15, 1926), Vol. 30, pp. 908-9. Guyed stacks built at the shop were erected in one piece.

Welding a 30-In. Diameter Gas Main. Australian Engng. Rec. (July 15, 1926), Vol. 3, pp. 14-15. Butt-welded pipe is given pressure, bending and dropping tests.

Welding Battered Joints Has Proved Economical. Fly. Engng. & Maintenance (September, 1926), Vol. 22, pp. 350-4. Electric arc and oxy-acetylene methods are both used.

Welding High Carbon Tool Steel and High Speed Steel with the Oxy-Acetylene Torch. G. L. Walker, Western Machinery World (August, 1926), Vol. 17, pp. 350-3. Illustrates some parts successfully welded and gives compositions of suitable steels.

Welding of Defective Work in the Machine Shop. P. L. Roberts, Machinery (London) (July 29, 1926), Vol. 28, pp. 502-4. Materials include steel and cast iron and non-ferrous articles.

Welding Pipe Lines in Buildings. H. E. Wetzell, The Welding Engineer (September, 1926), Vol. 11, pp. 34-38. Good welding needs advertising, type of pipe to pipe joints, types of branch joints, saving forty dollars on one joint, when welding saves money, order pipe with 40° bevel, strength of welded pipe, welded joints are tight joints, easy repairs-economy in covering, flexibility, use templets in pipe work, odd jobs that means big savings, welded steam lines in huge office buildings, flanges only where valves are used, field for U-bend of small radius.

Welding Plates Structures. J. N. Reeson. Brit. Pat. 254127. Ill. Off. Jnl. (Aug. 25, 1926), Vol. 38, p. 3546. Describes a butt and lap welding process.

Welding the New Stainless Steels. Canad. Mach. & Mfg. News (Aug. 19, 1926), Vol. 36, pp. 22-24. The semi-arc process is being used for welding nickel-chromium alloys and cast iron.

Welding Pipe Line, 22 Miles Long, Is Completely Welded. Iron Trade Rev. (Aug. 19, 1926), Vol. 79, p. 445. Steel pipe 22-24 inches in diameter is welded by electric arc.

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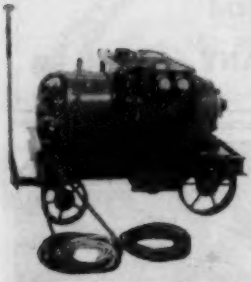

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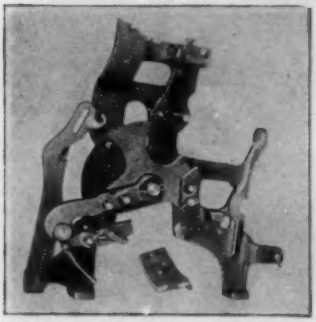

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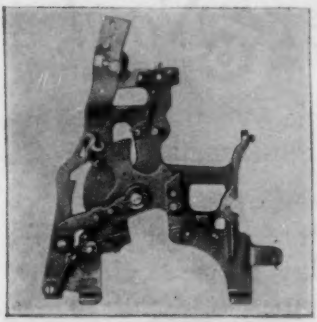

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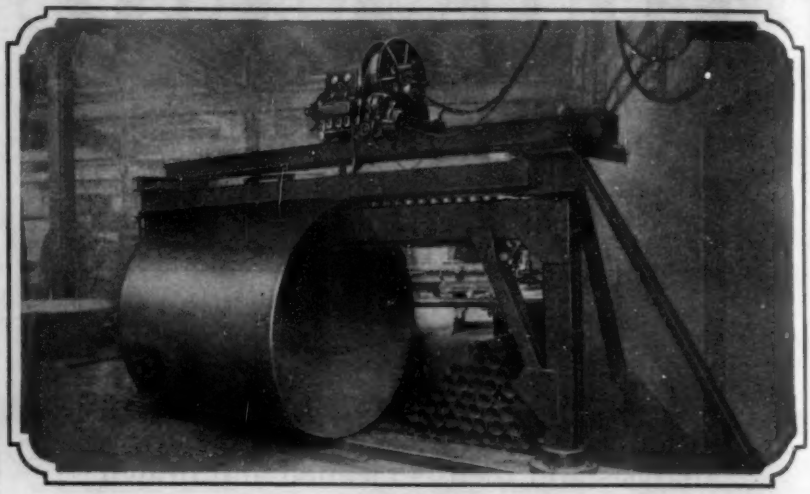

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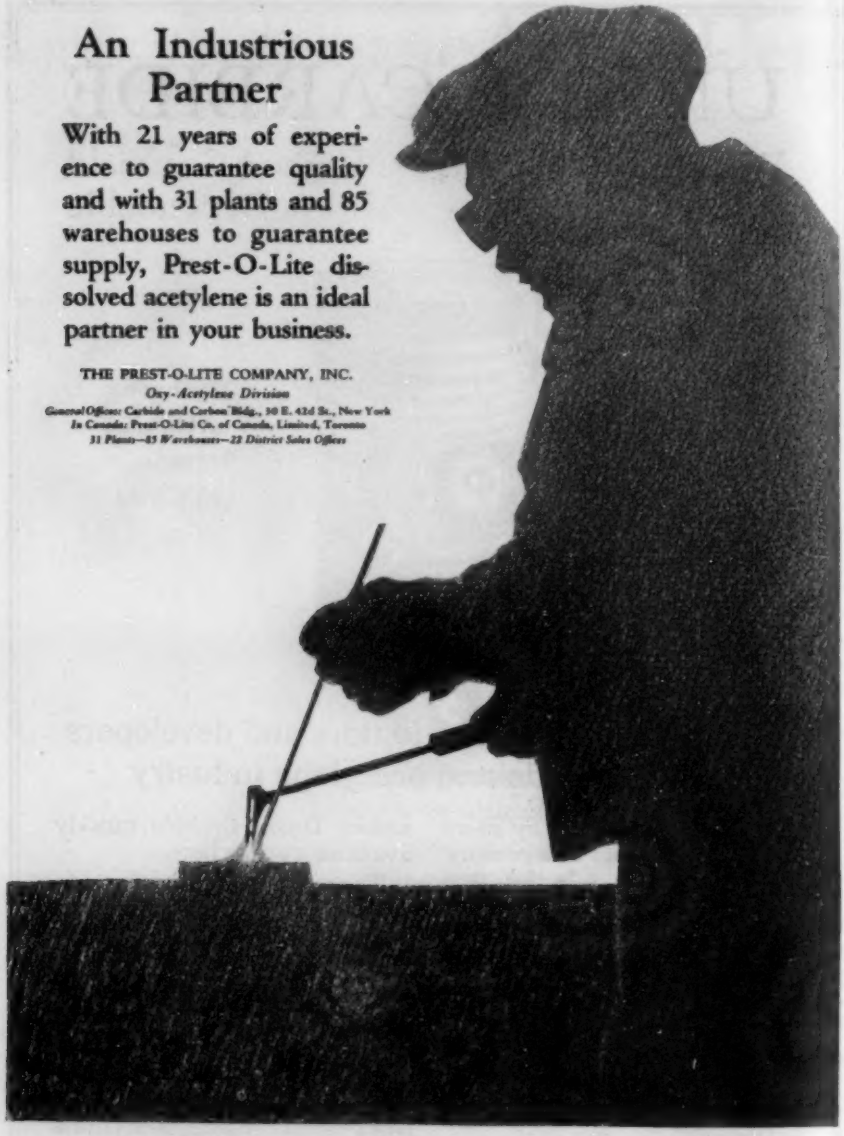

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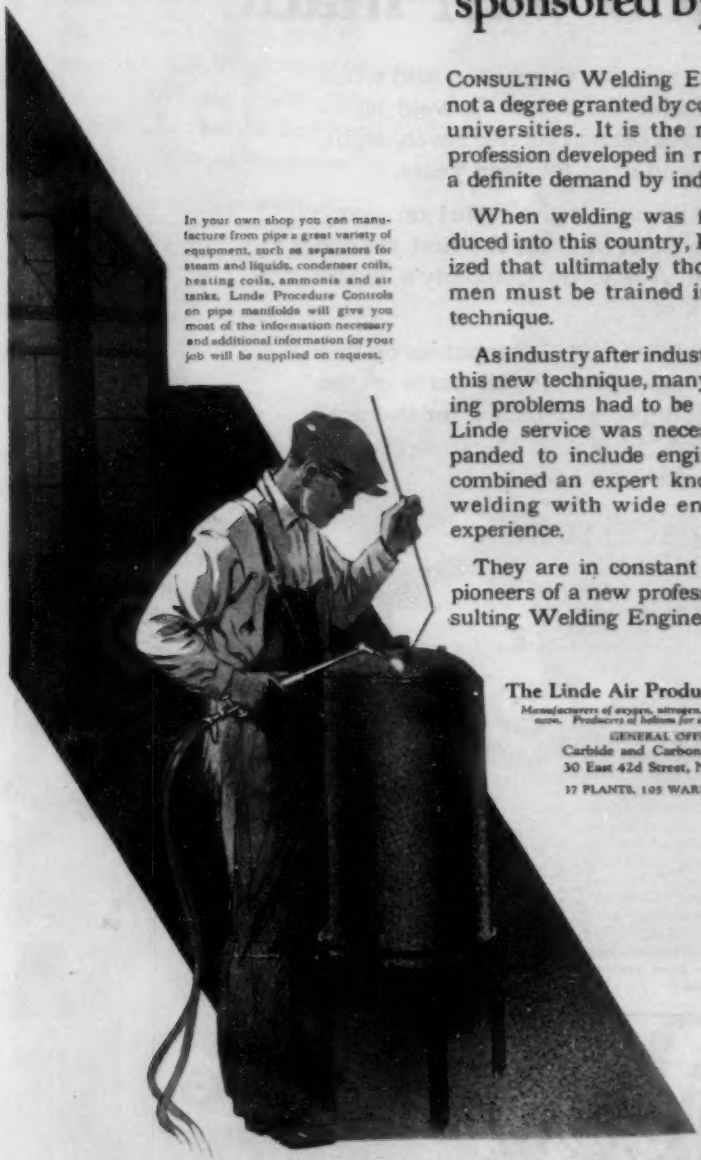
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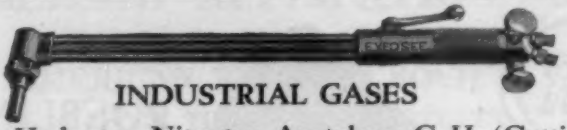

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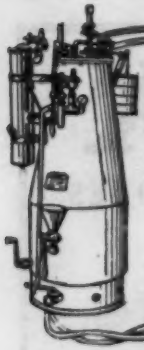

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Extract from By-Laws

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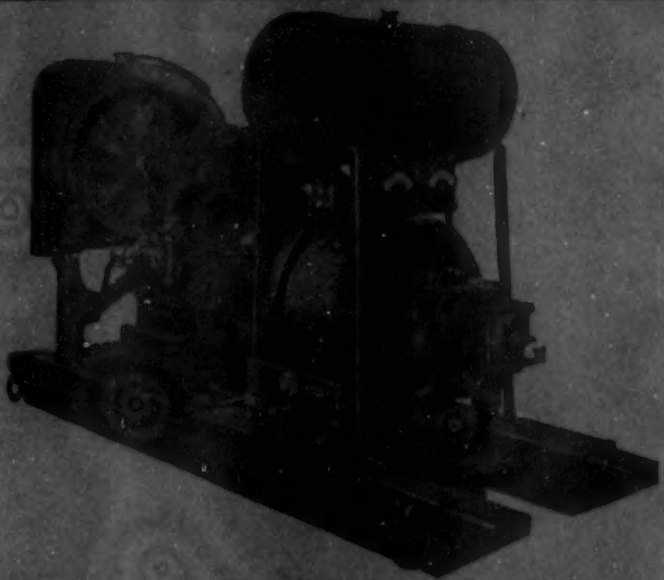

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Economical Operating Cost and
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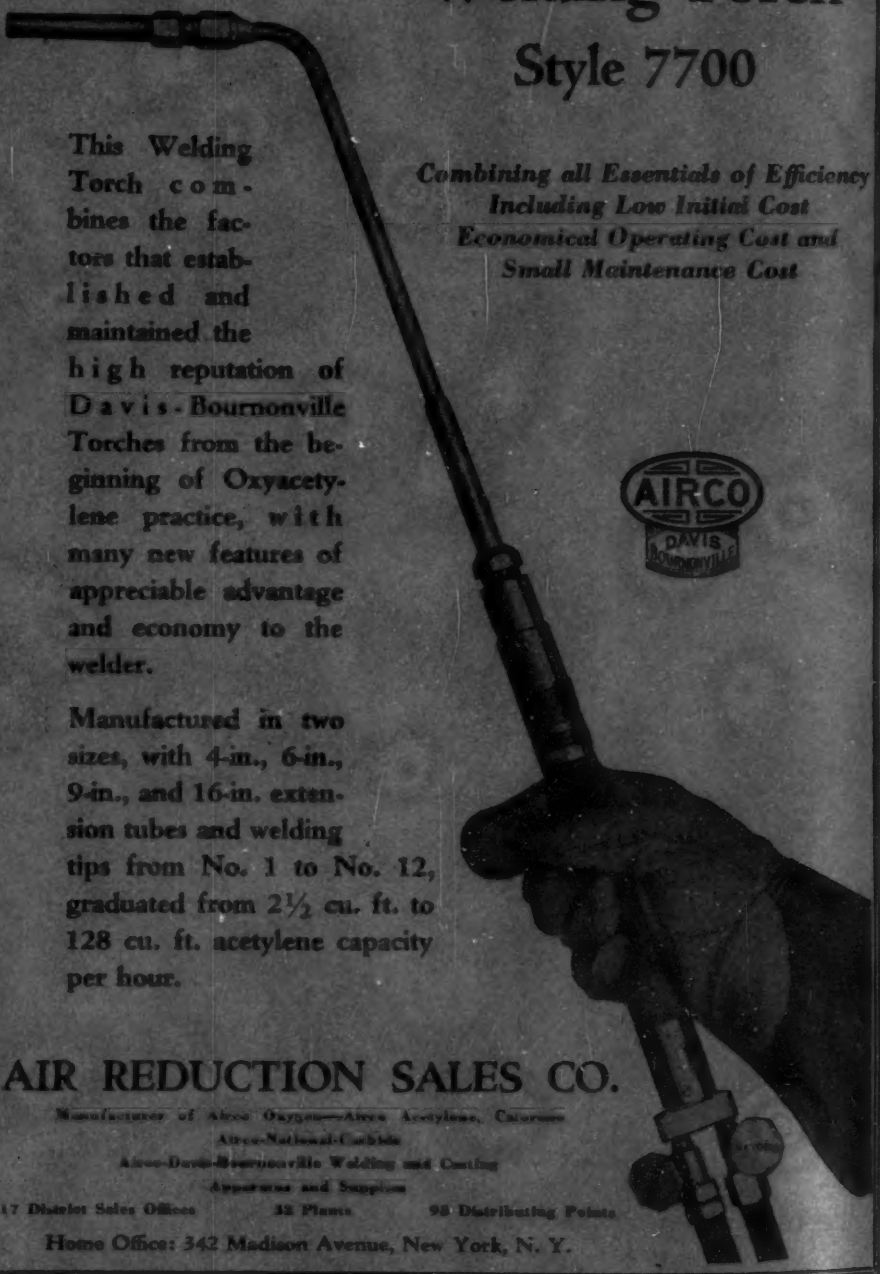

This Welding Torch combines the factors that established and maintained the high reputation of Davis-Bournonville Torches from the beginning of Oxyacetylene practice, with many new features of appreciable advantage and economy to the welder.

Manufactured in two sizes, with 4-in., 6-in., 9-in., and 16-in. extension tubes and welding tips from No. 1 to No. 12, graduated from 2½ cu. ft. to 128 cu. ft. acetylene capacity per hour.

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